DURBAN CONTAINER TERMINAL: CAPACITY ANALYSIS AND FEASIBILITY OF A DRY PORT CONCEPT

BY

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Abstract

This thesis presents an analysis of the Durban Container Terminal (DCT), which consists of Pier 1 and Pier 2. The study was conducted due to the DCT reaching its maximum capacity in the next few years. The main objective of this report was to identify the constraints which limit the annual container throughput, and to provide solutions to increase the annual container throughput capacity for the DCT.

The container throughput levels were analysed and projections were made. The capacity limiting constraints of the DCT were calculated and analysed. The study found that the container stacking yards were limiting the annual container throughput for Pier 1 and Pier 2. The annual container throughput that the stacking yards could handle was significantly less than the container throughput that the berths could physically achieve. It was calculated that the maximum capacity of the DCT was 3 600 000 TEU moves/year. This study found that the DCT would reach its maximum operating capacity between 2020 and 2024, under the current infrastructure.

Two expansion projects have been implemented by TNPA to increase overall capacity of the container terminal. The first was the deepening, widening and lengthening of berths on DCT Pier 2. Additionally, expansion plans include the reclamation of land between DCT Pier 1 and the Salisbury Island naval base. The effect that the proposed expansions would have on the capacity limiting constraints of the DCT were analysed. The expansions were calculated to increase the annual container capacity to around 5.2 million TEU moves/year. The equivalent container stacking yard capacity would still be limiting the DCT after the expansions are complete. From the analysis of container throughput projections for the DCT it was found that the terminal, after proposed expansions were complete, would reach its maximum operating capacity between 2027 and 2036.

The study analysed solutions to further increase the capacity of the DCT. The change in the stacking system from straddle carriers to a RTG “1 over 5” for Pier 2 was analysed. It was established that the above-mentioned change in stacking system would increase the annual capacity of DCT by around 980 000 TEU moves/year, to around 6 200 000 TEU moves/year. The change in stacking system was deduced to increase the overall capacity of the DCT, but a shortfall was still present between the equivalent container stacking yard capacity and the throughput that the berths could achieve. The effect of reducing the container dwell time was

analysed and it was established that the concept would greatly increase the overall container capacity of the DCT.

The ‘Masterplan’ is a solution that is recommended, which includes the above-mentioned change in stacking strategy, along with active dwell time control and the use of a dry port. The dry port concept would enable the DCT to implement strict container dwell time control, whereby containers exceeding a dwell time of 4 days would be transported to/from a dry port, via a shuttle train.

The use of a dry port as part of the ‘Masterplan’ would increase the capacity of the DCT to around 7.05 million TEU moves/year. Two locations were identified for the dry port site: the Bayhead Road site, which is located very close to the DCT and would allow for cost effective transportation of containers; the old Durban Airport site, which would require a much larger capital input than the Bayhead Road site. The Bayhead Road site can also make use of all the rail and road connections that serve the DCT, whereas the old Durban Airport site would require excessive construction to connect with the rail networks. The Bayhead Road site was deduced to be the most feasible location for a dry port.

The dry port concept is deduced as a feasible and plausible alternative for the DCT to increase its maximum annual container throughput capacity.

Opsomming

Hierdie tesis bied 'n ontleding van die Durban Houereindpunt (DCT) wat uit Pier 1 en Pier 2 bestaan. Die studie is uitgevoer omdat die DCT sy maksimumvermoë binne die volgende paar jaar sal bereik. Die hoofdoel van hierdie tesis is om die faktore wat die jaarlikse houerdeurvloei beperk, te identifiseer, om oplossings daarvoor te vind en om hierdie oplossings te evalueer.

Die houerdeurvloeivlakke is ontleed en vooruitskattings is gemaak. Die vermoëbeperkinge van die DCT is bereken en ontleed. Daar is bevind dat die houerwerf se deurvloei die jaarlikse houerdeurvloei vir Pier 1 en Pier 2 beperk. Die jaarlikse houerdeurvloei van die houerwerf is aansienlik minder as die deurvloei wat die kaaie fisies kan bereik. Die maksimumvermoë van die DCT met die huidige infrastruktuur is 3.6 miljoen TEU-bewegings / jaar. Volgens die vooruitgeskatte houervervoer sal hierdie maksimumvermoë waarskynlik tussen 2020 en 2024 bereik word.

Twee uitbreidingsprojekte is deur TNPA geïmplementeer om die algehele vermoë van die houereindpunt te verhoog. Die eerste was die verdieping en verlenging van die kaaie van DCT Pier 2. Daarbenewens, sluit die uitbreidingsplanne die herwinning van grond tussen Pier 1 en die naasliggende Salisbury-eiland se vlootbasis in. Die effek wat die voorgestelde uitbreidings op die vermoëbeperkinge van die DCT sal hê, is ontleed. Daar is bereken dat hierdie uitbreidings die jaarlikse houervermoë tot sowat 5.2 miljoen TEU-bewegings / jaar sal verhoog. Die verhoogde vermoë van hierdie uitbreidings is egter nie voldoende om die geprojekteerde toekomstige deurvloeivlakke te hanteer nie.

Daar is gevind dat die DCT ná die voorgestelde uitbreidings, sy maksimumvermoë tussen 2027 en 2036 sal bereik. ‘n Oplossing is ondersoek om die vermoë van die DCT verder te verhoog, naamlik, die gebruik van portaalhyskrane met rubberbande (“rubber tyred gantry crans” (RTG); met ‘n 1-oor-5-stapelstelsel) in die houerwerf van Pier 2 in plaas van buidelwaens (“straddle carriers”). Hierdie verandering in die houerwerfstelsel sal die jaarlikse vermoë van die DCT met sowat 980 000 TEU-bewegings / jaar tot 6.2 miljoen TEU-bewegings / jaar verhoog. Daar is egter gevind dat in terme van TEU-bewegings, die kaaivermoë steeds die houerwerfvermoë oorskry.

Die “Meesterplan” wat ontwikkel is, is 'n oplossing wat die bogenoemde verandering in houerstapelstrategie insluit, saam met aktiewe staantydbeheer en die gebruik van 'n droë hawe (“dry port”). Die droë-hawe-konsep maak dit maklik vir die DCT om aktiewe staantydbeheer

uit te oefen, waar houers met ‘n staantyd van meer as 4 dae, per trein na die droë hawe vervoer word.

Die gebruik van 'n droë hawe as deel van die meesterplan sal die vermoë van die DCT tot sowat 7.05 miljoen TEU-bewegings / jaar verhoog. Twee opsies is vir die droë-hawe-perseel geïdentifiseer, naamlik: (1) die “Bayhead Road”-perseel, wat baie naby aan die DCT geleë is en koste-effektiewe vervoer van houers sal toelaat en; (2) die ou Durbanse lughaweterrein, wat 'n veel groter kapitaalbelegging sal verg as die “Bayhead Road”-perseel. Die “Bayhead Road”-perseel kan ook van al die spoor- en padverbindings wat die DCT reeds het, gebruik maak terwyl die ou Durbanse lughawe-terrein aansienlike konstruksie sal vereis om byvoorbeeld, hierdie terrein met die bestaande treinnetwerk te verbind. Die “Bayhead Road”-perseel is as die mees haalbare opsie vir 'n droë hawe bevind.

Daar is gevind dat die droë-hawe-konsep 'n haalbare en aanvaarbare oplossing vir die DCT is om sy maksimum jaarlikse houerdeurvloei mee te verhoog.

Acknowledgements

I would like to express my gratitude to Professor K. Schoonees, and Mr. T. Bestenbreur, my research supervisors, for their guidance and critique for this research work.

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Nomenclature

CY – Container Yard

DCT – Durban Container Terminal

DDoP – Durban Dig-Out Port

DDP – Durban Dry port (proposed new dry port)

POD – Port of Durban

RMG – Rail-Mounted Gantry

RTG – Rubber-Tyred Gantry

STS – Ship-To-Shore

TEU - Twenty foot equivalent units (standard container size)

Chapter 1

Introduction

The Durban Container Terminal (DCT) is one of Africa's largest container terminals, which provides a crucial trade connection for Southern Africa to the rest of the world. The annual container throughput volumes have been growing over the last 10-15 years due to growth in South Africa's economy. Globalisation of trade also drove the growth of the container trade all over the world. The size of vessels has been increasing over the last ten years, which has put pressure on the ports to keep up with larger draughts and increased containerised trade. The expansion of the DCT is continuously investigated by Transnet, and is considered vital for the growth of South Africa's economy.

Transnet have been researching possible solutions to increase the DCT's annual container throughput. Expansion plans are currently (2016) being implemented to increase the handling capacity of the DCT. Furthermore, studies were conducted about the feasibility of a new container terminal, namely the Durban Dig-Out Port (DDoP). This new port was set to be constructed 11 km south of the current DCT. The DDoP was alleged to take the capacity of the DCT from 3.6 million TEU moves/year, to around 8.2 million TEU moves/year by 2040 (Manda, 2015) – (TEU = twenty foot equivalent units, standard container size).

Presently (2016), the construction of the DDoP was not deemed to be feasible due to large capital costs, environmental issues and associated financial risk. It was decided by the Transnet that a capital investment plan was to be developed to keep operating the current port and expand, where possible, to meet the demand for the next five to ten years.

Another possible solution to increase the container throughput capacity was proposed by Mr. Ton Bestenbreur. It involved the use of a dry port/inland terminal at a location close to the DCT. The dry port concept is discussed in Section 2.2. The new dry port would serve the DCT and is proposed to increase the annual container throughput for the port whilst also relieving traffic and congestion at the DCT.

This study focuses on analysing the capacity of the DCT for:(1) the present (2016) situation; (2) the planned expansion to the container terminal – starting in 2017. Once the constraints limiting the annual container throughput are identified the study focusses on developing solutions to increase the container throughput, for the DCT.

1.1 Background

The aim of this section is to provide a background on the Port of Durban (POD), specifically the DCT. The section then investigates at the growth of the DCT in terms of size and container throughput.

1.1.1 Brief history of the Port of Durban

The first written history of the area comes from Portuguese explorer Vasco de Gama who landed in the Natal area on Christmas day 1497. The history of the modern Port of Durban (POD) dates to 1824 when the first Europeans made a landing on the coast. The idea started with the intention of setting up a trade post. The Natal Bay in which the POD is located was one of the few natural harbours available along the east coast of South Africa.

In 1837, the Dutch Voortrekkers arrived in Natal and negotiated a grant of land from Zulu King Dingane, which included the area of the present POD. The Zulus and the Voortrekkers went through many battles over this land grant, before the Voortrekkers finally defeated the Zulu's in 1838. The British, who at that time had started forming colonies in South Africa, did not agree with the Dutch Voortrekkers being in control of the port. The British defeated the Dutch Voortrekkers in 1842 and took control of the POD in 1843.

Under the rule of a British governor, immigration to the POD increased. The thriving sugar cane industry led the exports for the POD, which was the busiest sugar terminal in the world.

With the explosion of the sugar cane industry, infrastructure was being constructed all around the POD. By the turn of the century (1900), the POD had roads, sewerage systems and railways.

The POD continued growing and expanding during the 20th century and saw the establishment of the container terminal in July 1977 (Transnet 2012). The container terminal stands presently as the 2nd largest container terminal in Africa, with Port Said in Egypt being the largest. The current DCT has two terminals, namely Pier 1 and Pier 2 (Figure 1). These two combined terminals handle around 65% of South Africa's container volumes (Transnet 2012).

The POD serves as a major hub for containers from the Middle East, Far East, Indian Ocean Islands and Australia. Current port expansions are underway to keep up with the global demand for increased container throughput and larger ship sizes to achieve this.

Figure 1 below shows the current layout of the POD:

Figure 1 Durban Container Terminal, Tristan (2015)

1.2 Problem statement, aim of study and project objectives

The problem statement for this project is that the annual container throughput of the Durban Container Terminal is approaching the maximum capacity that the terminal can physically handle. The terminal thus needs to expand to meet future container volumes that are predicted.

The aim of this project is to analyse the current DCT, and to determine which constraint(s) was limiting the maximum capacity of the terminal. Expansion projects have been implemented and the above-mentioned constraints are thus to be calculated for the terminal post expansion. Lastly the aim of this project is to provide solutions to further increase the capacity of the DCT.

The objectives of this project are summarised below:

I. To conduct a literature review of research which is relevant to this project:

II. To analyse the container throughput history for the DCT and analyse predictions/projections for future container volumes.

III. To determine which constraint(s) were limiting the current capacity of the container terminal. Two main capacities were analysed which could have been limiting the container throughput, namely the berth capacity and the equivalent container stacking yard capacity.

IV. To determine the effect that proposed expansions have on the capacity limiting constraints stated in Objective III.

V. To develop solutions for the DCT to increase the maximum container handling capacity, which include a change in stacking strategy for Pier 2, as well as a masterplan which includes active dwell time management and the use of a dry port to serve the DCT.

1.3 Methodology/Layout

The methodology of this report describes the process that was followed to meet the objectives stated in the previous section.

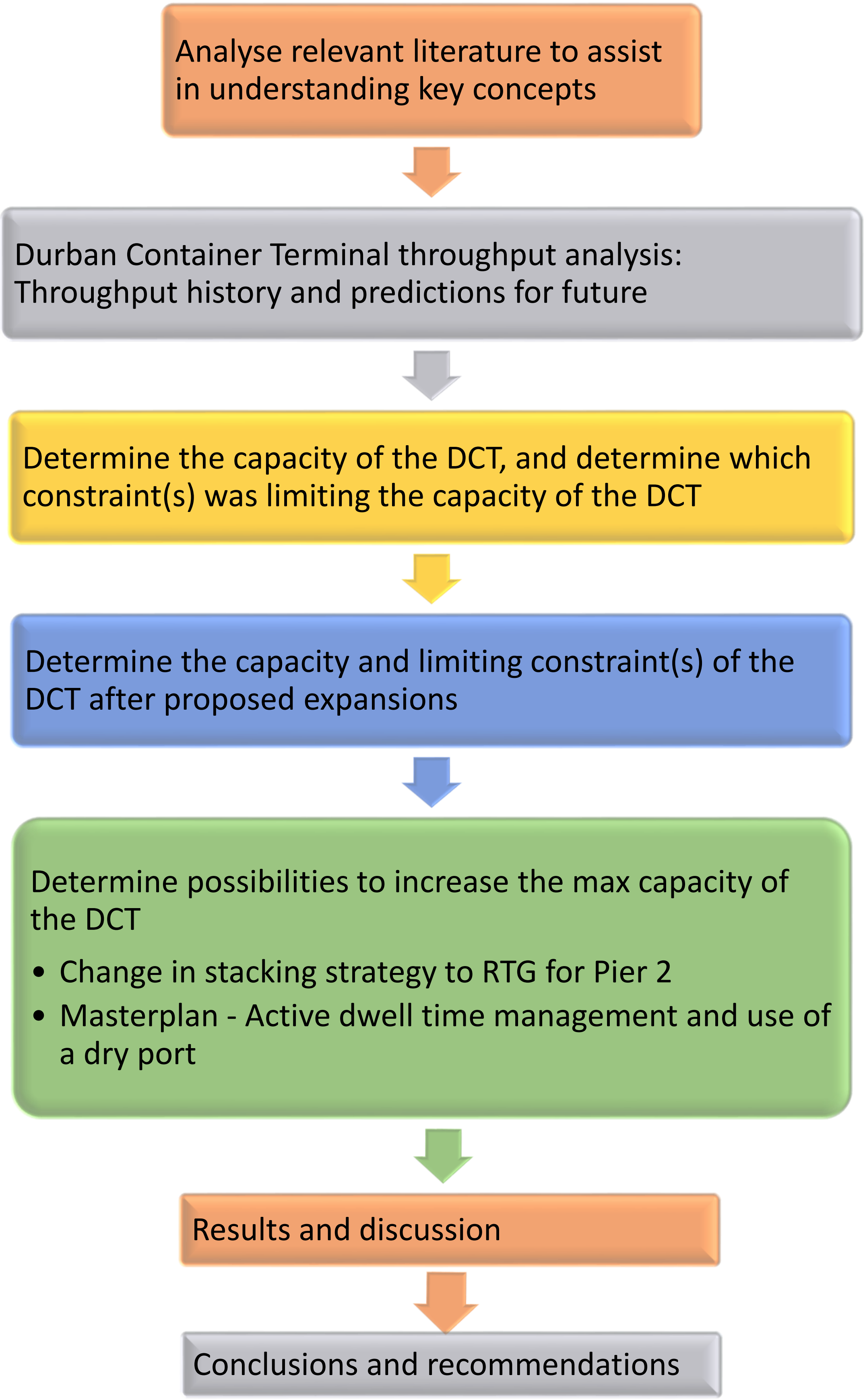

Figure 2 - Methodology followed for this report

1.5 Exclusions

The following aspects were excluded in this analysis:

- Numerical modelling of logistics – the handling of containers to and from ships, trains and trucks together with the temporary storage of containers, form a logistics transport system. Because this investigation is on a conceptual design level, no logistics modelling was undertaken. Once the feasibility of improvements has been established, logistics modelling must be carried out during the preliminary and detailed design.
- Economic/financial analysis – this thesis presents the feasibility from an engineering perspective, i.e. would the dry port physically increase the overall container throughput for the DCT. The economic analysis would have to be performed during the preliminary design stage.
- Environmental analysis – an EIA (Environmental Impact Assessment) would have to be completed before the dry port concept can be implemented. This is done to mitigate any environmental issues that arise from any associated activities and is required before any approvals will be given.

Chapter 2

Literature review

The literature review starts with presenting definitions of maritime container terminals. The review then goes on to analyse the global and national containerised industry. The review then covers the dry port concept, with relevant definitions and research. The chapter concludes with the description of constraints which limit the capacity of container terminals, and an explanation of the calculation thereof.

2.1 Maritime Container Terminals

The aim of this section is to provide definitions related to maritime container terminals which are relevant to this report. This section starts with the definition of a standardised container, followed by the definition of a maritime container terminal. The section then briefly analyses the type of equipment used in container terminals, followed by a brief overview of the global and national containerised industry.

2.1.1 Definitions

Standard containers are constructed of steel profiles and have a standard internal dimension of either 20ft or 40ft (5 895 mm or 12 029 mm). These dimensions describe the overall length of the container, whereby the height is standardised to 2 392 mm and the width to 2 350 mm, adapted from Transport Information Service (2015). Figure 3 shows the standardised container used in modern day container trade.

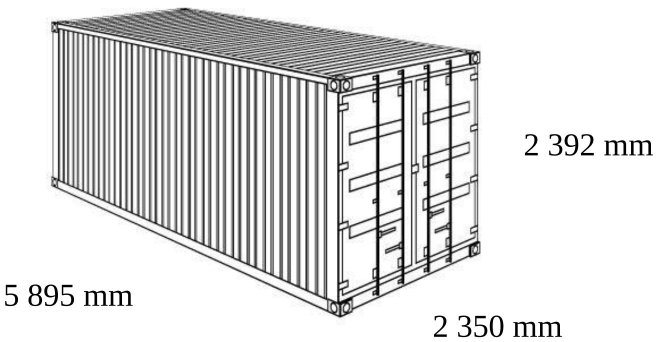

Figure 3 - Internal dimensions of a standardised 20ft container, Transport Informtion Service (2015)

The term TEU (Twenty foot equivalent units) is defined as a unit to standardise the number of containers that a port, vessel or mode of transport can handle, in a uniform manner. A forty-foot container is simplified as 2 TEU's, which makes the total number of containers uniform and easy to analyse. Containers can either be standard, refrigerated, open top, or a tank container (for transportation of liquids, gases and powders).

A maritime container terminal is defined as "a complex facility that involves a variety of different parts and processes, which consists of berths for ships, cranes for transfer of containers between the terminal and the ship, yards for storage of containers, gates for entrance and exit, and several other subdivisions for equipment and administration", Committee on Productivity of Marine Terminals. (1986).

The operations of maritime container terminals are simplified in Figure 4. The berthing area is known as the area where vessels are moored (anchored to land) to be loaded/offloaded; the apron area is the area set aside for loading and offloading of containers to and from the vessels; the container stacking yard area is used for the storage of containers; the connection to the hinterland area is where containers arrive of depart the terminal destined to, or arriving from hinterland areas (the hinterland is known as areas which are located inland from the maritime ports). The terminal equipment is used for the efficient transportation of containers between the vessels, the container stacking yard and the road and rail terminals. This will be discussed in Section 2.1.2.

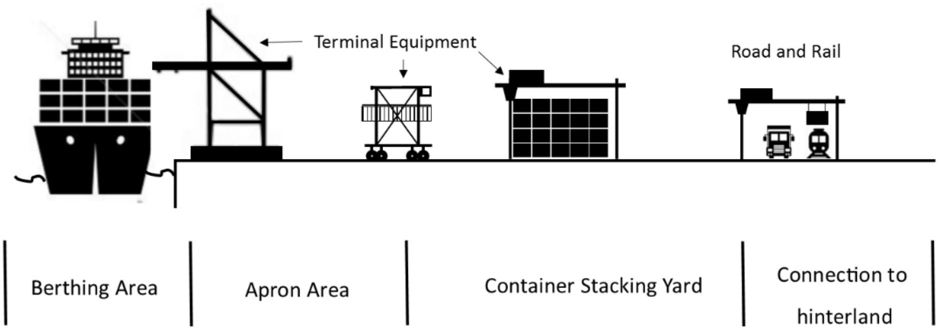

Figure 4 - Schematic representation of modern day container terminals

The total capacity of container terminals is defined as the number of TEU moves/year. This includes import, export and transhipment moves. This capacity is limited by several constraints which will be outlined in Section 2.3.

2.1.2 Design Vessels and Terminal Equipment

This section briefly analyses the different vessel types and container terminal handling equipment used in modern day terminals. Rodrigue (2013) stated in "The Geography of Transport Systems", that since the 1950's, container ships undertook six general waves of changes, each representing a new generation of container ship. These generations are summarised below:

- **Early container ship** – these were the first container ships and were composed of modified bulk vessels or tankers that could transport around 1000 TEUs. These ships were slow and only carry containers on their converted decks and not in their bellyhold. Once the container trade kicked off the construction of the **fully cellular containerships (FCC; Second generation)** was completed in the beginning of the 1970's, and these ships were now dedicated to container handling.
- **Panamax** – During the 1980's there was a push for larger container ships by the larger economies. This push originated from the concept of the larger the ship, the larger the number of containers carried, the lower the cost per TEU was. The Panama Canal limited the size of ships, and thus the Panamax standard was the next generation of container ships. They could handle a maximum of around 4000 TEUs. Due to the limitations of the canal, the ships tended to go toward longer, narrower ships. In 1985, the Panamax Max took the maximum capacity to around 4500 TEUs.
- **Post Panamax –** going beyond the panamax class was perceived as risky, due to the width limitations at the Panama Canal, as well as the handling equipment at ports and the draft limitations of such a large ship. The APL C10 containership class, with a capacity of 4500 TEUs, was introduced in 1988 and was the first class to exceed the 32.2m width limitation of the Panama Canal. By 1996, full fledged Post Panamax containerships were introduced with capacities reaching 6600 TEUs (Post Panamax I). Due to the growth in the global shipping trade, ports were upgrading to accommodate bigger ships. By the late 1990s the ships reached 8000 TEUs (Post Panamax II). These container ships require a large draft, which put pressure on ports to dredge to accommodate Post Panamax containerships.
- **New-Panamax, or Neo-Panamax (NPX)** – these refer to ships that fit exactly in the locks of the expanded Panama Canal. These ships have a capacity of around 12 500 TEUs. These ships define a specific ship class that is able to efficiently service the Americas and the Caribbean, either from Europe or from Asia.

- **Post Panamax III and Triple E** – By 2006, the third generation of post panamax containerships arrived when Maersk shipping line introduced a class having a capacity between 11 000 and 14 500 TEUs; the Emma Maersk. They were given the nickname "Post New Panamax" since they are larger than the specifications of the extended Panama Canal. A further expansion of the post panamax led to the introduction of the **"Triple E"** class ships of around 18 000 TEUs in 2013. These ships are limited to mostly serve routes between Asia and Europe.

Figure 5 below shows the timeline and specifications of the changes in containerships over the last 70 years:

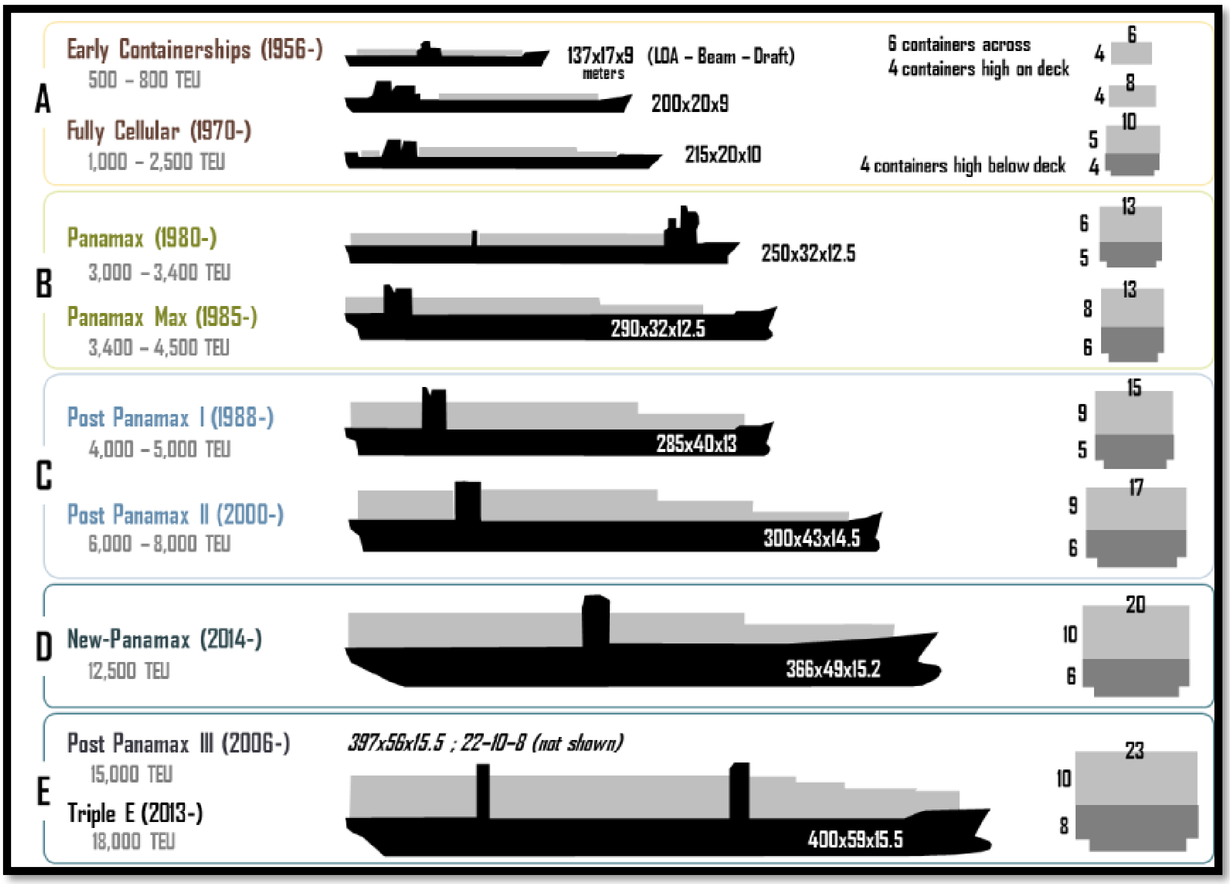

Figure 5 - Generations of containerships, Rodrigue (2013)

In order to determine a maximum capacity for the DCT it must be investigated what the current vessel limitation is. Morwe (2014) showed in the Port Development Plan the following table which shows the sizes of ships that the SA ports can handle.

Table 1- Maximum ship sizes for SA ports, Morwe (2014)

Vessel	Side view	Dimensions (LOA x beam x draft)	SB	CT	PE	Ng	EL	Dig - out	Dbn	RB
Container: Feeder 3 000 TEU		210m x 30m x 11,0m		✓	✓	✓	✓	✓	✓	✓
Container: Panamax 4 500 TEU		240m x 32m x 12,0m		✓	✓	✓		✓	✓	
Container: Post Panamax 6 600 TEU		305m x 40m x 14,0m		✓		✓		✓	✓	
Container: Ultra large 15 000 TEU		400m x 59m x 15,5m				✓		✓		

According to Morwe (2014), the maximum vessel size that the DCT could handle was a post panamax. Mpoverello (2013) stated that the MSC Fabiola set the record for the largest container ship to dock at the DCT. The MSC Fabiola measures in at around 360m, with a capacity of 12 562 TEUs, Marine Traffic (2017).

STS cranes are a type of large dockside gantry crane which is used for loading and unloading containers from container ships. Although cranes have been used in harbours from the Middle Ages, the modern STS cranes were established in the mid 1950's with the emergence of containerised trade. STS cranes consist of a supporting framework that can traverse the length of a quay or yard on a rail track.

The STS cranes can be divided into different sizes:

- Panamax – can fully load and unload ships that can pass through the Panama Canal, which is usually 12-13 containers wide;
- Post-Panamax – can fully load and unload ships too wide to pass through the Panama-Canal, normally 17 containers wide;
- Super-post-Panamax – these are the largest STS cranes and serve ships that are up to 23 containers wide.

Smith (2012), The Tioga Group Inc, stated that the modern crane maximum productivity is **35 moves/h** and that cranes were usually available for **16 hours/day**.

Figure 6 below shows three of the largest modern STS cranes, which now operate in the Port of Khalifa, UAE:

Figure 6 - Modern STS cranes, Khalifa Port, UAE, World Maritime News (2014)

Containers need to be moved and stacked in an efficient and cost effective manner. Modern day container handling equipment has developed substantially over the last decade, with the following systems being widely used across most container terminals: The Reach stacker system, Straddle Carrier system, Fork-lift truck, Rubber-Tyred Gantry (RTG), Rail-Mounted Gantry (RMG) and Automated Stacking Cranes (ASC). The above-mentioned systems are shown in Figure 7.

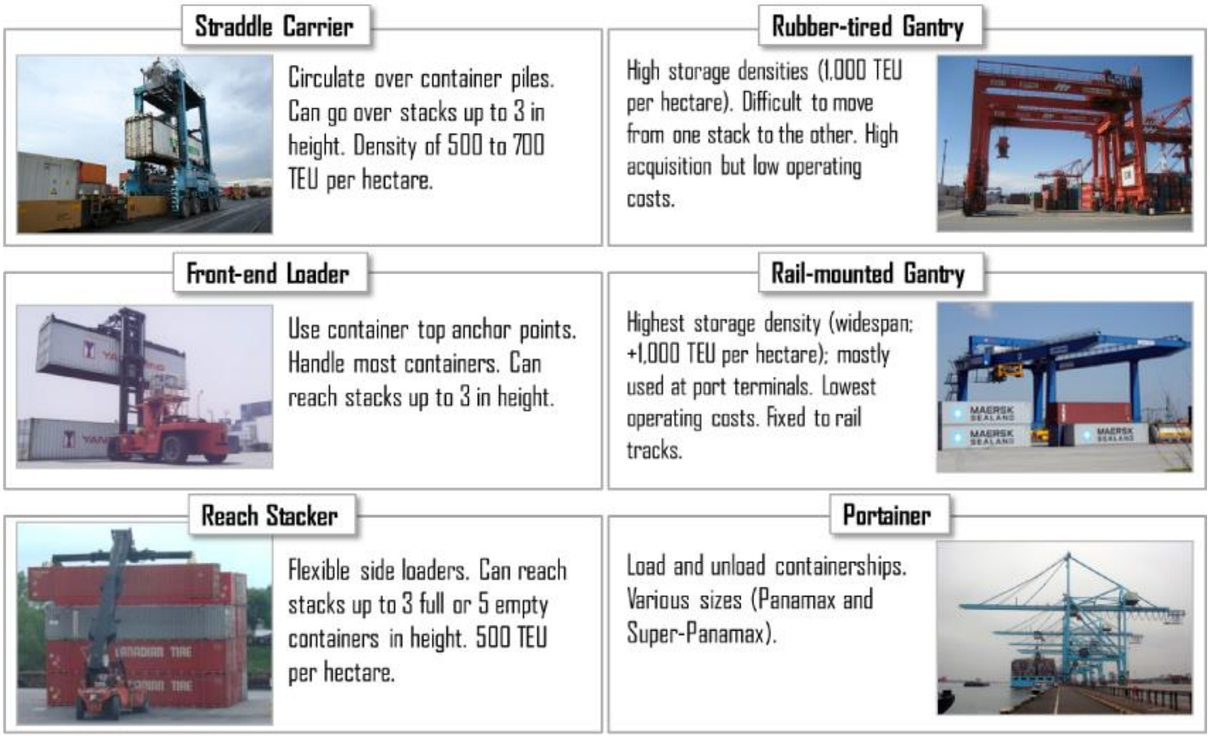

Figure 7 - Container terminal handling equipment, Rodrigue (2013)

The biggest factor in determining which system is adequate is the stacking height. The stacking height brings with it two characteristics which affect the total throughput, as well as the productivity. A larger stacking height will increase the total number of containers in the stack, but will decrease the accessibility of an individual container in the stack.

Table 2 summarises each system by analysing the stacking height, effective storage capacity, and the advantages and disadvantages of each system:

Table 2- Summary of container handling equipment

Type of system	***Storage capacity (TEU per hectare)***	***Effective Stacking height***	***Advantages***	***Disadvantages***
Reach stacker	500	4 in second row, 3 in first row	Low capital costs, multi-purpose operations, flexibility	Needs to run in conjunction with tractor/trailer
Straddle carrier	500-750	3	High flexibility, can handle high traffic volume, can move and stack containers	Low stacking height – less container

				throughput for area
RTG	1100	5-6	Low operating and maintenance costs, good solution for large terminals, high storage capacity	Only used for stacking, require tractors/trailers for movement of containers
RMG/ASC	1100	5-6	High stacking capacity, stable and works efficiently, works well with large terminals	Limited flexibility-can only operate on a rail track

Figure 8 below shows the practical storage capacity for each type of system described above:

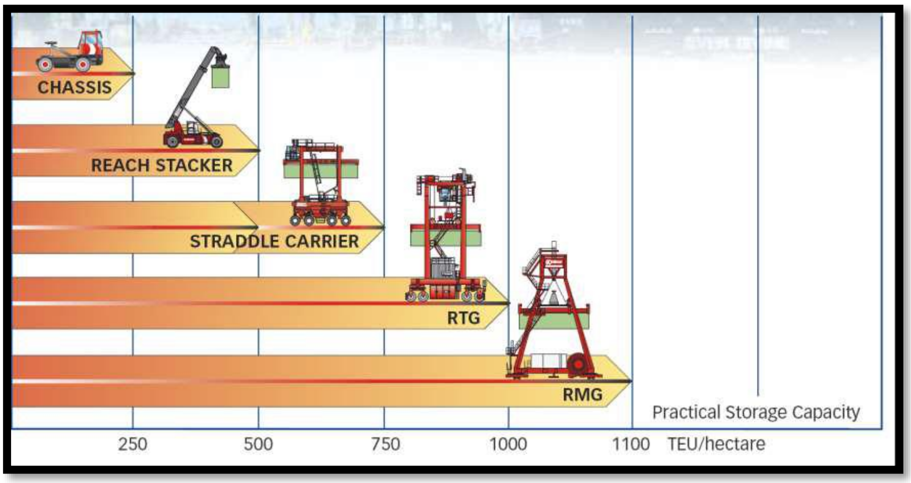

Figure 8- Typical capacities of container handling equipment, Kalmar (2008)

This section aimed at identifying the various types of container vessels, as well as the container handling equipment that is used in modern day terminals. The subsequent section will briefly analyse the containerised industry on a global and national level.

This section briefly analyses the state of the container trade globally and nationally. This enabled the researcher to understand the container industry, and to make accurate predictions for the future container volumes for the Durban Container Terminal.

2.1.3 Containerised Trade Industry

This section of the report aims to briefly analyse the containerised trade industry. The section starts off with a history of container trade, followed by an overview of growth rates in container trade globally and nationally.

2.1.3.1 History of container trade

The history of container trade dates back to the 26th of April, 1956, when a World War 2 tanker was converted into a storage container by Malcom McLean. The tanker, dubbed “Ideal X”, made its maiden voyage from the Port of Newark to the Port of Houston. Within 10 years shipping companies had commissioned dockside container cranes to handle containers at an unheard rate of 20 moves per hour. This whole concept led to the globalisation of the container trade which is explained in the section below.

2.1.3.2 Globalisation of trade

The growth of international trade started with the basic principle of demand. International trade takes place between countries to gain a comparative advantage. This is achieved through the reduction of labour, acquisition of cheaper/more abundant resources, location of markets and demand for certain products. This led to the development of transportation links between countries, whereby the cheapest way to transport cargo across sea was large ships.

Further development of trade was achieved through economic trade policies between countries. The BRIC trade agreement was started in 2006 between Brazil, Russia, India and China, which aided in the growth of world trade. In 2010, South Africa joined the trade agreement to develop the country’s economy after the 2008/2009 recession. Due to the location of South Africa between the large economies that form part of BRICS, SA’s trade industry saw an increase in international trade.

For this study the figures of growth of international container trade was analysed. Unescap (2015) indicated a growth in world trade of around 8.5% between 1980 and 2000, followed by an annual growth rate of 6.6% from 2000 – present.

The growth of world container trade can be seen in Figure 9 below:

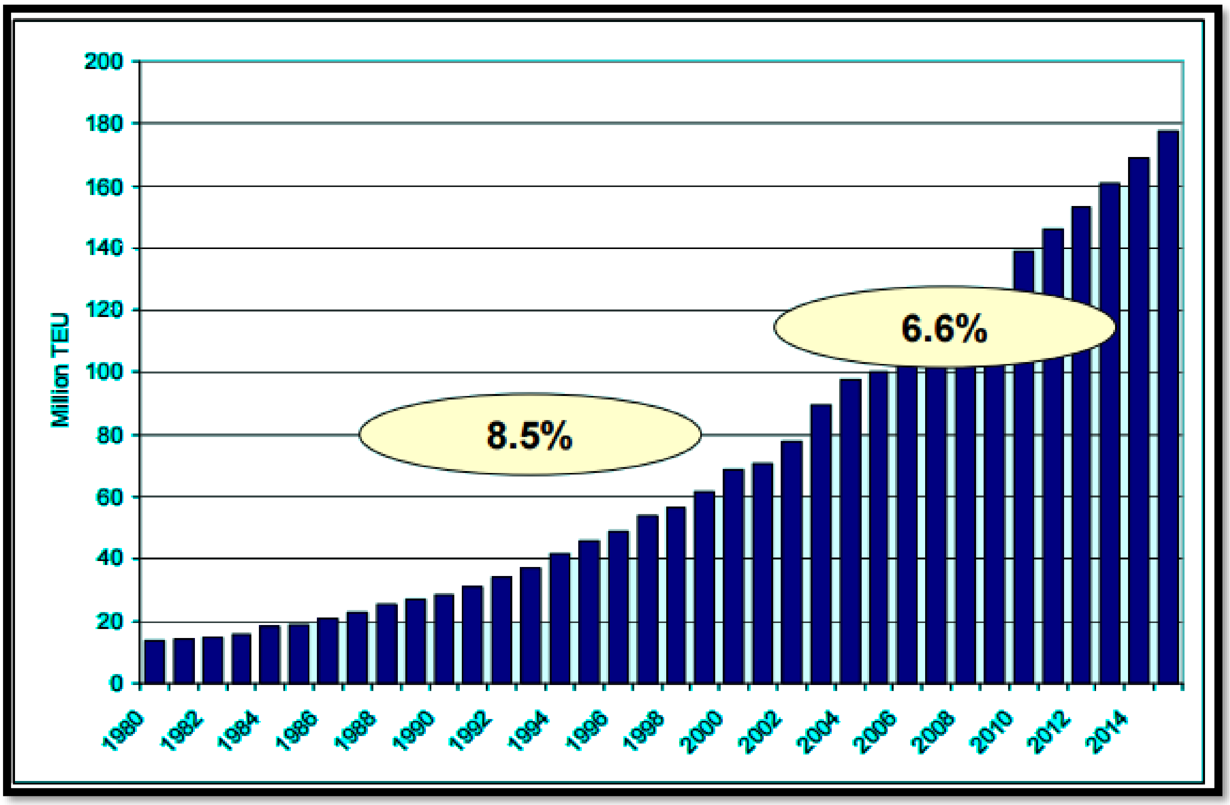

Figure 9- Growth rate of container trade, Unescap (2015)

As can be seen in Figure 9 the growth of the container industry has been growing over the last 35 years and continues to grow. For this study projections of global trade will not be analysed, however, the projections for the container throughput for the DCT will be analysed and can be seen in section 4.

2.1.3.3 South African container trade

This section will briefly overview the growth of container trade in South Africa over the last couple of years. The section will only analyse the growth rate of the total container throughput of South Africa, as Chapter 3 includes a full throughput analysis on the DCT.

The South African container volumes have followed a similar growth pattern to global trade, whereby the industry saw a general decrease in container volumes between end 2008 and mid-2009, due to the global recession. The South African container trade bounced back well after the recession, which can be seen in Table 3:

Table 3- South African Container Volumes TEU moves per annum, Transnet Limited (2015)

	2008	2009	2010	2011	2012	2013	2014	2015
(mil TEU)	3,738	3,8	3,629	4,081	4,352	4,403	4,641	4,844

The values depicted in Table 3 represent the total annual throughput, in million TEU's, for South Africa's container terminals combined. The container trade industry in South Africa continued to grow over the last ten years and is forecasted to continue with this trend with a 6% per annum growth rate (Transnet Limited, 2014) over the next few years.

Figure 10 below shows the container volumes for South Africa for the last seven years:

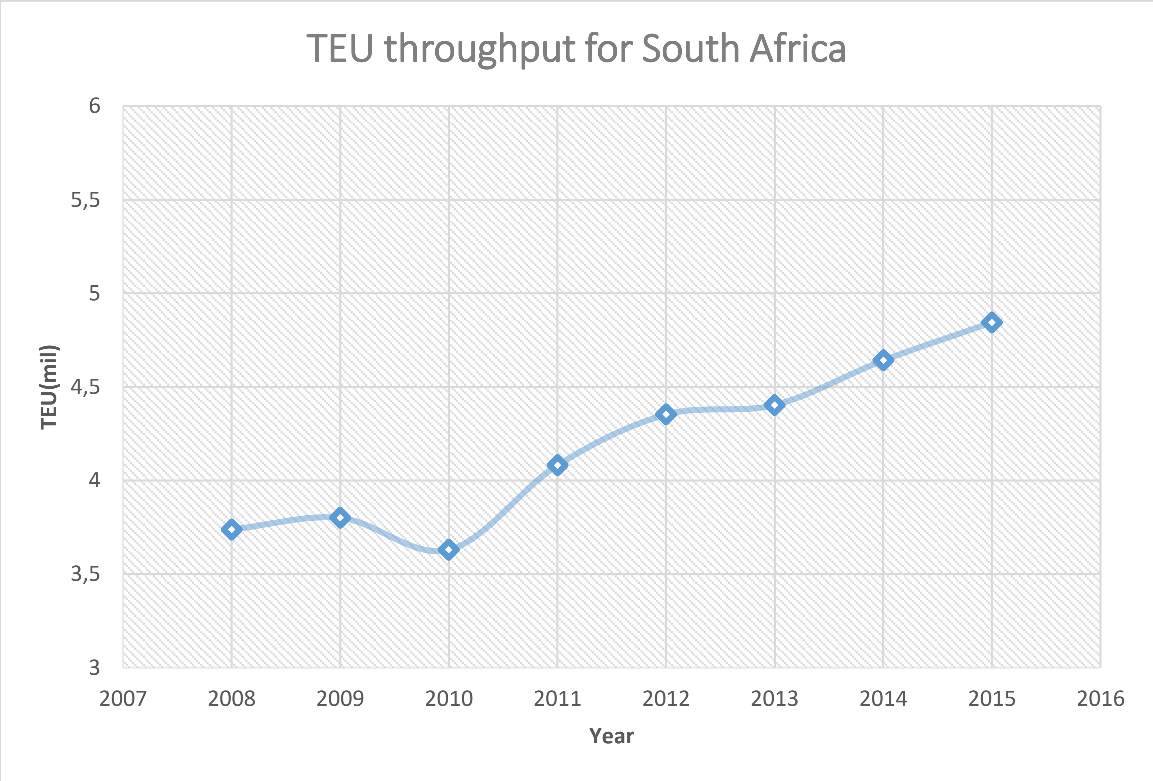

Figure 10 - Container Volumes for South Africa

Figure 10 shows that the overall container volumes for South Africa grew from around 3.7 million to over 8.4 million TEU moves/year between 2008 and 2015. There was a noticeable decrease in the container volumes between 2009 and 2010. This was due to the global recession of 2009, which had a significant detrimental effect on global economies, and subsequently the container trade. The container trade in South Africa bounced back in 2011 and continued growing at a steady rate until 2015.

The DCT has been the leading container terminal for South Africa, by volume, for many years. With around 60% of South Africa's containerised cargo being handled by the terminal, the efficiency and quantity of container activity is crucial to the DCT. The container volumes for the last 5 years were analysed to represent the container volume split for South African ports. The information was supplied by Nandkuar (2016) and can be seen in Figure 11:

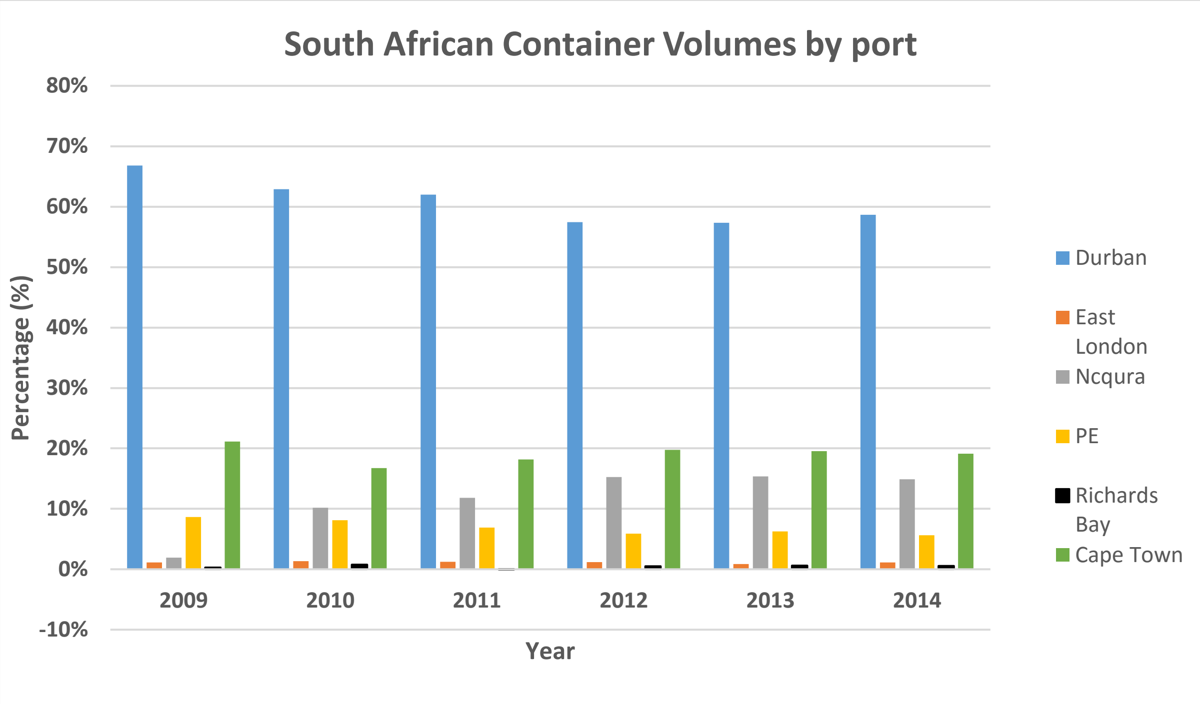

Figure 11 - South African Container Volumes by port, adapted from Nandkuar (2016)

The above figure shows the dominance by the DCT in terms of container throughput for South Africa. Due to the growth of Ncqura and Cape Town container terminals the percentage of South Africa's container volumes that the DCT provided decreased between 2009 and 2012.

The subsequent section will analyse the dry port concept, which is relevant to this report due to a dry port forming part of the "Masterplan" solution to increase the capacity of the DCT, see Section 5.2

2.2 Dry Port concept

The following section provides a background on the dry port concept. The dry port concept is an important factor in increasing the capacity of the DCT. This section will look to define the concept of a dry port, functions of a dry port and various factors that drive the rise of a dry port. Practical examples of dry ports across the globe will also be evaluated and the success/failure of the dry port will be examined.

2.2.1 Definition of a dry port

The definition of a dry port has the same general concept but terminology may differ from region to region. It is thus that this project will focus on the global definition for a dry port.

Originally the 'dry port' was defined as an inland terminal to and from which shipping lines could issue their bills of lading, with the concept initially being applicable to all types of cargo (UNCTAD, 1982). With the rapid expansion of containerization, the definition shifted towards 'a place inland that fulfils original port functions (Cullinane and Wilmsmeier, 2011).

Roso and Lumsden (2011) stated that the dry port concept 'is based on a seaport directly connected by rail to inland intermodal terminals where shippers can leave and/or collect their standardized units as if directly at the seaport'. They also stated that progress only in the maritime part of the transport chain and seaport terminals is not sufficient for the entire chain to function efficiently. They stated that improvements in the seaport inland access (i.e. rail and road to dry port or further hinterland connections) are crucial.

The dictionary of international trade stated that the dry port concept allows for the smooth flow of customs formalities outside of the port area, under supervision by local customs agencies, and thus alleviates the traffic flow for the actual port.

Leitner and Harrison (2001) stated that when defining inland ports, 'inland ports can be sites where congested ports are relieved, many services are provided at one location, or local and regional development is promoted'. It was also specified that inland ports provides the means to move international trade locations away from congested border and traditional maritime ports.

Gooley (1997) stated that inland ports provide a complete range of services. These services include all range of transportation (rail, road, air – not applicable to DP, pipelines), distribution, warehousing and logistic-management services. The consolidation of all these services makes inland ports attractive to shippers and logistic managers, and promotes the efficiency of supply chains.

Rodrigue and Notteboom (2013) indicated that the term 'dry port' was subject to debate due to some of these terminals having direct access to inland waterway systems. It was stated that there is no consensus on the terminology resulting in a wide range of terms including dry ports, inland terminals, inland ports, inland hubs, inland logistic centres etc. It followed that three fundamental characteristics were related to an inland port/dry port:

- An intermodal terminal, either rail or barge that has been built or expanded
- A connection with a port terminal through rail, barge or truck services
- An array of logistical activities that support the freight transited

From the definitions that were reviewed it can be concluded that the general concept and functions of a dry port are similar. These definitions all include the concept that the dry port provides extra storage capacity to maritime ports, while providing a stern structure to distribute, store and manage cargo.

From the above studies the definition of a dry port is given below:

A dry port is an inland cargo terminal at a location outside of the main ports where storage, stacking, distribution and transportation promote overall efficiency of the maritime port. This is achieved by consolidating all services related to the port, which in turn enhances the development and improvement of the port that it is associated with.

Figure 12 below shows the impact of a dry port and the effect that it can have on cargo movement:

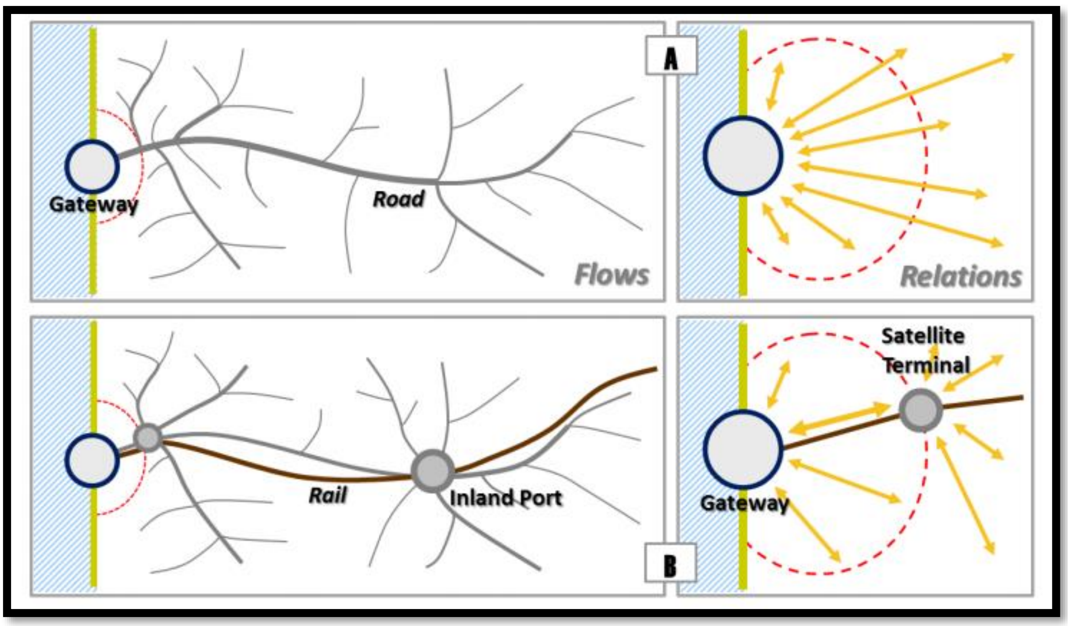

Figure 12- Modal Shift and Inland Freight Diversion before (A) and after the Insertion of an Inland Port and Satellite Terminal, Rodrigue and Notteboom (2013)

2.2.2 Functions of a dry port

This section analyses the various functions of dry ports that have been researched. The section will analyse the overall function of a dry port as well as specific physical functions.

The first research that was analysed was that of Rodrigue and Notteboom (2013). The functions of a dry port were explained as follows:

It was stated that inland ports/dry ports serve three non-exclusive functions and are given below:

Satellite Terminal

These terminals tend to be close to the port facility, predominantly at the periphery of the metropolitan area, as their primary function is to service seaport facilities. They help to relieve congestion at the main port terminal and serve functions that have become too expensive such as warehousing and empty container depots. Satellite terminals can also serve as load centres for local or regional markets and are connected to the main port via rail or barge shuttle services.

Freight distribution clusters (load centres)

These terminals are located further away than satellite terminals. They serve as a major intermodal facility which provide access to regional markets that include production and consumption services. These tend to take place in logistic parks and free trade zones. The inland load centre thus serves as a point of collection or distribution of a regional market. If the load centre has a good intermediary location, such as along a rail corridor, then freight distribution to an extended market can take place.

Transhipment facilities

These facilities link large systems of freight circulation either through the same mode (e.g. rail to rail) or through intermodalism (rail to truck, rail to barge). In the later case, the inland terminal serves as a load centre. The source and destination of the cargo is outside the terminal's market area, with such terminals often being located at the country borders due to the goal of combining administrative processes linked to border traffic and value-added logistics activities

Figure 13 below shows the above-mentioned functions as defined by Rodrigue and Notteboom (2013):

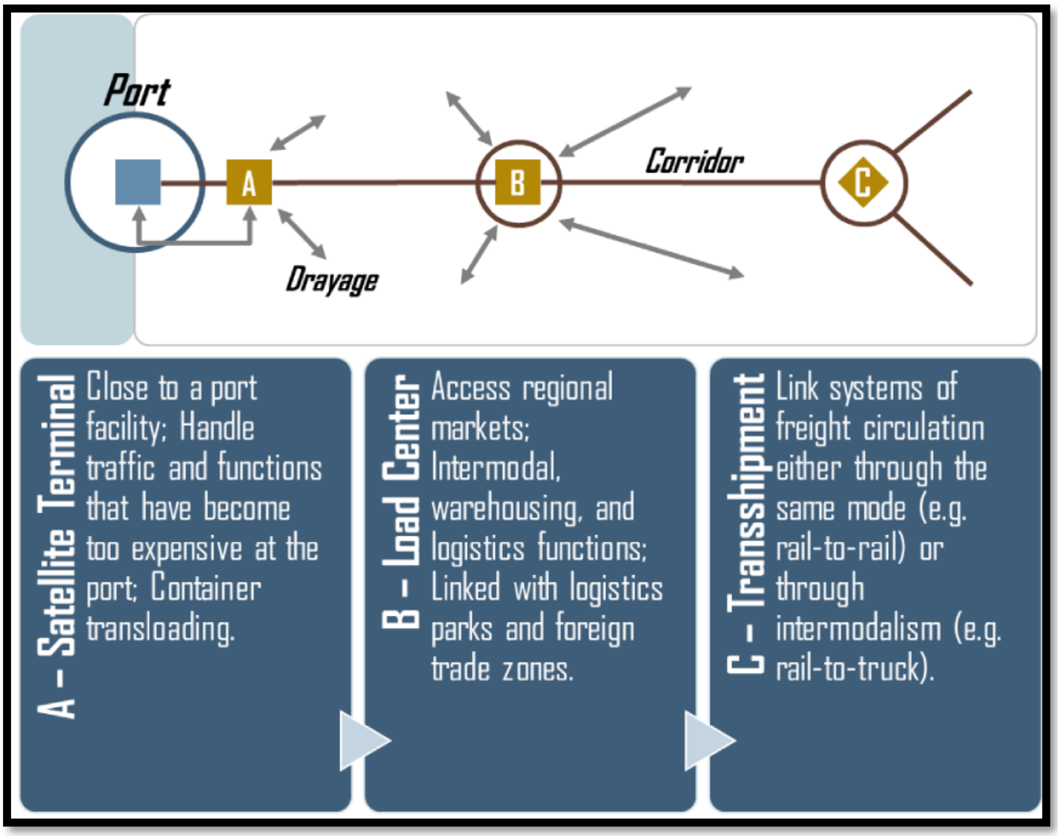

Figure 13- Functions of an inland terminal, Rodrigues and Notteboom (2013)

This study states that these functions are non-exclusive, which means that the inland terminals can serve several functions at once. It is thus that there is no single model for an inland port. Considering the diversity of functions that inland terminals can serve, Rodrigues and Notteboom (2013), mentioned three major criteria that ensure the efficiency of the terminal to serve its role as an interface between global and regional freight distribution systems:

A study conducted by The Tioga Group, Inc (2006) concluded that for a port to meet its objectives it needed to accomplish the following functions:

- **Processing** the goods to increase their value. “Processing” includes refining, sorting, assembling, packaging, testing etc. or any other process that increases the value of the goods to the customer.
- **Consolidation** – the process of adding value to the goods by linking the handling and transportation of goods. This can include the consolidation of multiple small shipments into a single, larger and more efficient shipment. Consolidation can also be achieved by linking the delivery of multiple items into a single delivered product.

- **Distribution** – the process of splitting large shipments into smaller shipments for local delivery. The distribution, or "deconsolidation" includes the following examples:
    - Wholesale to retail
    - Transfer between rail, road and maritime shipments
    - Transhipment at container freight stations
- **Customs inspection** – containers are inspected for any illegal substances or objects. These include contraband (drugs), undeclared or misdeclared cargo, undeclared weapons, stowaways etc. The Customs and Border Protection relies primarily on the Automated Targeting System (ATS), which classifies shipments to be physically inspected based on origin, destination, commodity, shipper/consignee etc.

Leitner and Harrison (2001) stated that an inland port provides services, which can be seen as functions, and are summarized below:

- **Provision of available modes of transport** for cargo to reach its final destination.
- **Distribution** – as discussed above
- **Warehousing and storage** – providing enough warehousing and storage space for any containers/cargo which cannot leave the dry port immediately.

Trainaviciute (2009) found that for a port to achieve its objectives of successfully moving cargo it should achieve the following functions:

- **Transhipment of cargo between transportation means** – this function requires the dry port to have specialised equipment to be able to transfer units from one transportation mode to the other. Dry ports usually shift cargo from road to rail transport and vice versa.
- **Sorting** – containers have to be sorted as a number of supply chains are involved with the transportation of cargo. In order to achieve less congestion in the main port terminal, the sorting and distribution of cargo is performed at the inland dry port.
- **Storing** – the storage of goods can take different intervals of time. If the goods are used for distribution they are stored for a long period of time. If goods are used for transhipment from one mode to another the storage time periods are a lot shorter than for distribution. Lastly the dry ports can be used for storage of empty containers, and thus alleviates space and pressure on the main port that it is serving.
- **Management of container flows to different ports** – this function is relevant when the dry port has connections and communications to more than one port in an area.

- **Consolidation of individual container flows** – containers from different shippers are consolidated by loading onto one train or truck headed for the same area – thus a saving in expenses.
- **Reduction of road traffic** – by using a dry port the total amount of road transport is reduced due to the consolidation of containers and use of rail transport.

2.2.3 Driving forces of a dry port

Rodrigue and Notteboom (2013) stated that there were some deficiencies in the conventional inland freight distribution that needed to be mitigated. This mitigation includes:

- **Input costs** – land and labour remain amongst the significant logistics costs. Many maritime terminal facilities have limited land available for expansion, which is the case for the Port of Durban, whereas inland terminals often have land available. Many ports face higher labour costs due to being in metropolitan areas, which results in the search for lower value locations supporting less intensive freight activities.
- **Capacity and congestion** – this has been found to be the main driver of inland dry ports development since a system of inland terminals increase the intermodal capacity of inland freight distribution. Dry ports reduce the overall congestion of maritime ports, especially traffic generated by large trucks, this due to rail networks that relieve the maritime port of containers, as well as reducing the amount of trucks that visit the main port terminal.
- **Hinterland market** – through long distance corridors between the main port terminal and the dry ports, a higher level of accessibility is achieved. This is due to lower distribution costs and improved capacity. These long distance corridors allow ports to penetrate hinterland markets which extends their cargo base.
- **Supply chain management** – an inland port is a location which is actively unified within supply chain management practices, in particular with containerisation. It links the ports with transport companies and supply chain managers.

2.2.3 Existing dry ports

The following section gives a broad overview of existing dry ports. Three dry ports that operate successfully were analysed. These dry ports were chosen due to them successfully implementing the dry port concept This part of the report was done to give an indication of key factors that contribute to the success of a dry port.

2.2.3.1 Dry Port Azuqueca de Henares

The first of such a site and established in 1995, the Dry Port Azuqueca de Henares is joint owned by the state and private sector. The dry port is located 30km from Madrid, and has daily rail connections to the Port of Barcelona (600km), Bilbao (400km) and Santander (400km). Azuqueca is a multi-cargo dry port, with a breakdown of 70% containers and 30% bulk (Monios, 2011). It is located on an area of 47 700 m^2.

The container throughput of the dry port was 2000 TEU in 2001, with the throughput rising to 25 000 TEU in 2008. The throughput dropped to 15 000 TEU in 2009. Of this, approximately 50% was from Barcelona, 40% from Bilbao and 10% from Valencia (Monios, 2011). Figure 14 shows the Azuqueca de Henares dry port.

Figure 14 - Azuqueca de Henares dry port, Gran Europa (2014)

From the review of the Azuqueca de Henares dry port the following factors were identified as a part of the success of this inland terminal:

- Location – close to Madrid, the capital city of Spain;
- Usability – the dry port is used by three large commercial ports in Spain;
- Link to transport infrastructure – rail link to three ports allows efficient cargo flow.

2.2.3.2 Virginia Inland Port, Front Royal, Virginia

The Virginia Inland Port (VIP) is an intermodal container transfer facility in Front Royal, Virginia, and is owned by the Virginia Port Authority. The terminal is located around 100km from Washington D.C and occupies around 647 947m^2. The VIP brings the Port of Virginia 350km closer to inland markets. The inland port enhances service to the Washington D.C/Baltimore Metro Region by providing a rail corridor between the VIP and Hampton Roads marine terminal. The VIP has a TEU throughput of 78 000 TEU moves/annum (Port of Virginia, 2015).

The terminal is serviced by 5400m of rail track which connects to the Norfolk Southern Crescent Corridor via Harrisburg, PA, and the New York region. These rail connections provide a direct link to the marine terminals in Hampton Roads and operates five days a week. The facility is a U.S Customs designated port of entry, and thus a full range of customs functions is available to the customer. The location of the Virginia Inland Port is shown in Figure 15.

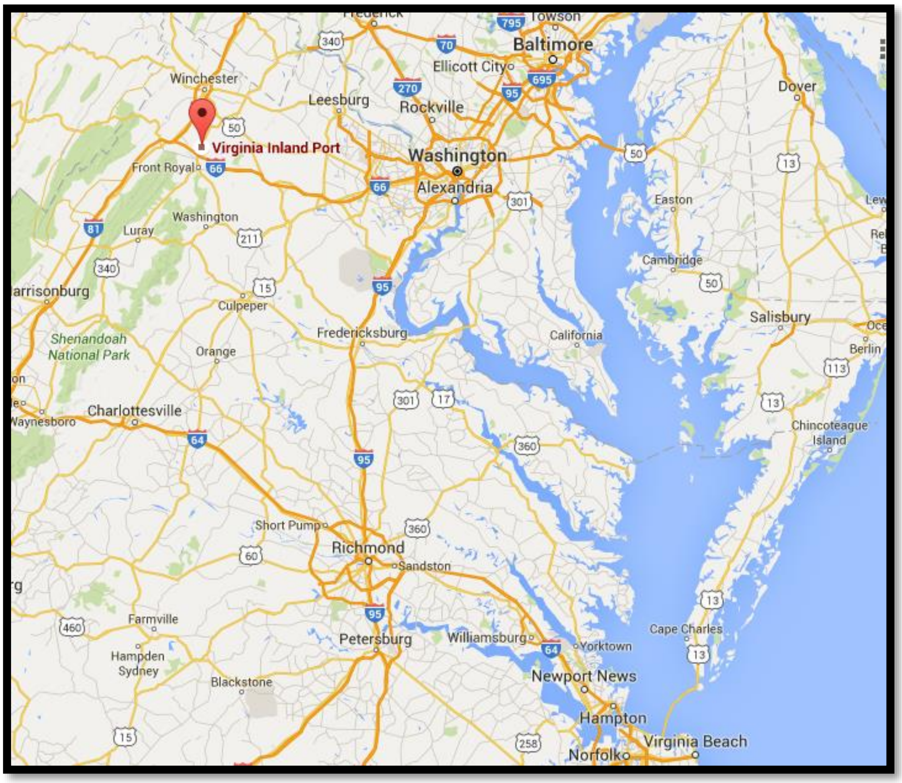

Figure 15 - Location of Virginia Inland Port, Google Maps (2016)

The VIP has functioning rail services and is also in a good location for road transportation. The VIP is located very close to the I66 and I81. These interstate freeways make for efficient road transportation which increases the overall throughput of the port. Due to the fast connection that the terminal has to the maritime terminals the VIP generated new business which resulted in large capital investments from the private sector. The Tioga Group, Inc, 2006, reported that the new business resulted in a capital investment of around $600 million. The layout of the dry port is shown in Figure 16.

Figure 16 - Layout of the Virginia Inland Port, The Port of Virginia (2015)

From the review of the Virginia Inland Terminal the following factors were found to lead to the success of this inland terminal:

- Transportation link to maritime terminals and hinterland markets – the VIP has very efficient links via road and rail, which increases the business opportunities for the Port of Virginia;
- Flexibility – the VIP made room for change which helped the terminal grow to where it is today.
- Synergy between the VIP and maritime ports – the efficient connections between the two lead to a strong relationship between the Virginia Port Authority and Norfolk Southern (rail operator).

- Design of the terminal is efficient. As seen in Figure 9 above, the design allows for smooth traffic flow by ensuring organised container storage and efficient movement of containers inside the terminal.

2.2.3.3 City Deep Container Complex, Johannesburg, South Africa

Johannesburg is Africa's largest city and is located around 600km from the Port of Durban. The city is in Gauteng, and is located around 50km from South Africa's capital, Pretoria. Although being located far from any maritime ports, 70% of freight cargo in South Africa is destined for, or originates in, the Gauteng province.

The City Deep Container complex was constructed in 1977 as an inland terminal for import and export cargo from the ports of Cape Town, Durban, East London and Port Elizabeth. The inland terminal has full customs facilities which allows for inbound traffic to be transported directly to Gauteng.

The inland port has recently been upgraded by Transnet, whereby an R800 million upgrade was completed. This upgrade doubled the TEU throughput to 400 000 TEUs / year (SA News 2015). This meant the City Deep Container Complex now stands as the largest dry port in Africa.

The terminal handles 300 trucks a day and loads and offloads up to 10 trains per day between Durban and Johannesburg (SA News 2015). The terminal operates 24 hours a day, 7 days a week. Figure 17 shows the City Deep dry port located in Johannesburg, South Africa.

Figure 17 - City Deep Container Complex, MPoverello (2013)

From the review of the inland terminal in Johannesburg City Deep, the following factors were identified for the success of this dry port:

- Location – the inland terminal is located adjacent to a large rail network which serves the Gauteng area, and has connecting lines to the Port of Durban
- Centralised location – the inland terminal is located in a market which imports and exports a large amount of cargo, which is also on the increase, and thus there is always a demand for cargo shipment
- Throughput – the City Deep Container Complex can handle 400 000 TEUs/year, which makes it the largest dry port in Sub-Saharan Africa.
- Strong relationship between the dry port and maritime ports – the City Deep Container Complex handles a large number of containers per day. The relationship between the dry port and maritime ports is crucial to the efficient and successful implementation of such a port.

2.2.4 Critical factors for the success of a dry port

From the above investigation of some dry ports across the globe, and locally, the following 5 factors that are required for the successful implementation of a dry port were identified:

- **Location** – the location was deemed to be a crucial factor of a successful dry port. The dry port needs to be located close to a large regional market, such that customers can import and export cargo efficiently to and from this dry port. The dry port also needs to be located at a distance from the maritime port to assist in relieving congestion at the port.

- **Demand** – for a dry port to be profitable there needs to be a large demand for such a facility. This demand is present if the majority of containers travels a long way to the end location. From all the dry ports analysed, they were all located close to a large city/town, whose local economy required a service to reduce transport costs of importing and exporting cargo.
- **Transportation corridor** – from all the dry ports that were analysed, it was prevalent that all had an efficient transportation corridor between the dry port and the maritime terminal. This was usually achieved via rail networks. The Virginia Inland terminal for example had connections to the Norfolk Southern line which ensured a quick and efficient link between the inland terminal and the maritime ports that it was serving. It also had a great location which was close to two main interstate highways, which ensured that the road cargo transportation could be achieved as smoothly as possible without creating congestion.
- **Initial investment** – for the construction of the dry ports that were analysed, the reduction and limitation of the initial capital costs was crucial. These costs can accrue quickly and thus a strategic plan was always drawn up. The investment plan should always include a development plan for future expansion.
- **Strong relationship** – between the inland dry port and the maritime port(s) that it is serving. The dry port should also aim to build a strong relationship with transportation and logistical owners. In the analyses of the Virginia Inland Port it was found that the relationship between the dry port and the Norfolk Southern ensured the successful development and growth of the terminal. This relationship improved overall transportation of cargo to the area, and thus created new business opportunities to the dry port.

2.3 Capacity Limiting constraints of Container Terminals

The capacity of a container terminal is defined as the maximum number of TEU moves that the terminal can achieve per annum (TEU moves/year). This capacity is limited by two main constraints: (1) The Berth Capacity – which is the number of TEU moves/year that the berths can physically handle and (2) The Container Stacking Yard Capacity – which is the number of TEU moves/year that the container stacking yard generates. Other constraints which affect the capacity, but are considered as variable and can be easily altered are: (1) The container crane capacity, (2) The rail terminal capacity and (3) The road terminal capacity. These constraints were also analysed and can be seen in Appendix B. Figure 18 shows the capacity limiting constraints for modern day container terminals.

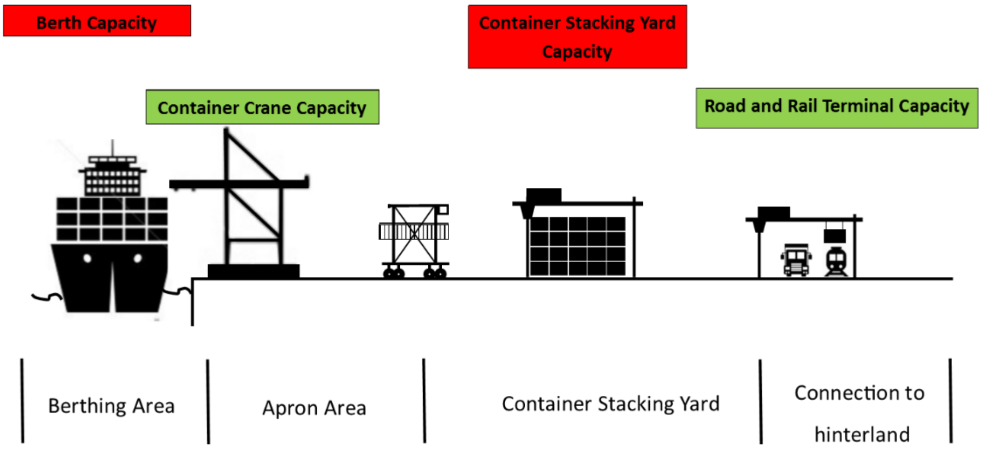

Figure 18 - Capacity limiting constraints for container terminals

2.3.1 Berth Capacity

This section shows the calculation of the throughput/capacity that the berths of a container terminal could physically handle. The berthing capacity was calculated using two methods which are explained in each subsection below.

2.3.1.1 Ligteringen Method

This method was calculated using the formula proposed by Ligteringen and Velsink (2012) as follows:

$$Cb = p \times f \times Nb \times tn \times mb$$

Equation 1

Where: Cb = average annual number of TEU per berth (TEU/yr)

p = gross production per crane (moves/hr)

f = TEU factor

Nb = number of cranes per berth – **assumed as 3.5** for modern day container terminals

tn = number of operational hours per year (hours/yr)

mb = berth occupancy factor (%)

2.3.1.2 The Bestenbreur method

Bestenbreur (2016) stated a rule of thumb used in the calculations of berth capacity as the following:

- 125 000 Container moves / 100m of available quay length
- 1 Container Crane for every 100m of quay side length

The above assumption is based on a crane productivity of 25 Cont. moves/hour, which is a crane productivity that most modern day terminals should be achieving. This method takes the total length of berths available for container related activity, and calculates the maximum number of container moves per year, which is then multiplied by the TEU factor to get the number of TEU moves/year that the berths can achieve.

2.3.2 Container Stacking Yard Capacity

This is defined as the maximum number of container moves/year that the stacking yard can achieve. This should equal or exceed the berth capacity for a container terminal to be operating at optimal efficiency.

The capacity of the container stack yard was calculated using formulas adapted from Bestenbreur (2015). The method used equates the operational container yard inventory to the effective inventory that the container stack can provide. The two equations can be seen below:

$$\begin{pmatrix} Max\ Operational \\ CY\ Inventory \\ TEU \end{pmatrix} = \left(\frac{Qdi + Qlo}{365}\right) \times \left(\frac{1 - \frac{1}{2}Tr\%}{100\%}\right) \times PF \times TEUfactor \times Dwell\ time$$

Equation 2

$$=$$

$$\begin{pmatrix} Max\ Effective \\ CY\ Inventory\ (TEU) \end{pmatrix} = \begin{pmatrix} Available \\ no.of \\ CY\ groundslots \end{pmatrix} \times \begin{pmatrix} Max\ effective \\ stacking\ height \end{pmatrix} \times n1 \times n2 \times n3$$

Equation 3

It was required to work out the total number of moves that the container stack yard can generate. This is represented by Qdi + Qlo above, and can be seen in Equation 8:

$$(Qdi + Qlo) = \frac{\begin{pmatrix} Available \\ no.of \\ CY\ groundslots \end{pmatrix} \times \begin{pmatrix} Max\ effectie \\ stacking\ height \end{pmatrix} \times n1 \times n2 \times n3}{\left(\frac{1 - \frac{1}{2} Tr\%}{100\%} \right) \times PF \times TEUfactor \times Dwell\ time \times \frac{1}{365}}$$

Equation 4

Where:

- Qdi + Qlo:= the total number of containers that are loaded and discharged to/from the container vessels per year. This is then multiplied by the TEU factor to obtain the number of TEU moves/year.
- Max effective stacking height = the maximum number of containers that can the container handling equipment can handle. (RTG: 5 , Straddle Carrier: 3)
- PF = Peak factor – Accounts for peaks in container volumes during certain times of the year. See Appendix B.2.
- Dwell time = the average number of days that a container dwells/remains in the container terminal.
- Tr % = the percentage of containers that are transhipped (i.e. containers that arrive at the terminal but depart via another vessel to another container terminal)
- TEU factor = factor to account for the number of 40ft containers that the terminal handles (usually between 1.4 and 1.7).
- n1 = Average stacking height/Max. Effective stacking height
- n2 = Peak average stacking height/average stacking height
- n3 = Ground slots Utilized/Ground slots available

Table 4 - n1,n2,n3 factors for terminal handling equipment, Bestenbreur (2015)

	Maximum Effective Stacking Height	η_1	η_2	η_3	Container Yard Inventory per 1000 TEU – Ground Slots	
					Effective (TEU's)	Maximum Effective (TEU's)
RTG "1 over 6" Tractor - Trailer	6	0.62	1.20	0.85 - 0.95	$\left.\begin{array}{c}3162\\-\\3534\end{array}\right\} 3373$	$\left.\begin{array}{c}3794\\-\\4241\end{array}\right\} 4018$
RTG "1 over 5" Tractor - Trailer	5	0.70	1.14	0.85 - 0.95	$\left.\begin{array}{c}2925\\-\\3325\end{array}\right\} 3125$	$\left.\begin{array}{c}3392\\-\\3790\end{array}\right\} 3591$
Straddle Carrier "1 over 3" Direct	3	0.83	1.10	0.95 - 1.00	$\left.\begin{array}{c}2365\\-\\2490\end{array}\right\} 2428$	$\left.\begin{array}{c}2602\\-\\2739\end{array}\right\} 2671$

2.4 Hinterland Connectivity of DCT

This section of the literature study will aim to investigate the current hinterland connections that the Port of Durban has to major metropolitan areas. Most the demand comes from the Gauteng area. Figure 19 below shows the concentration of economic centres in South Africa, as well as the movement of cargo from main metropolitan areas to area with limited access to services:

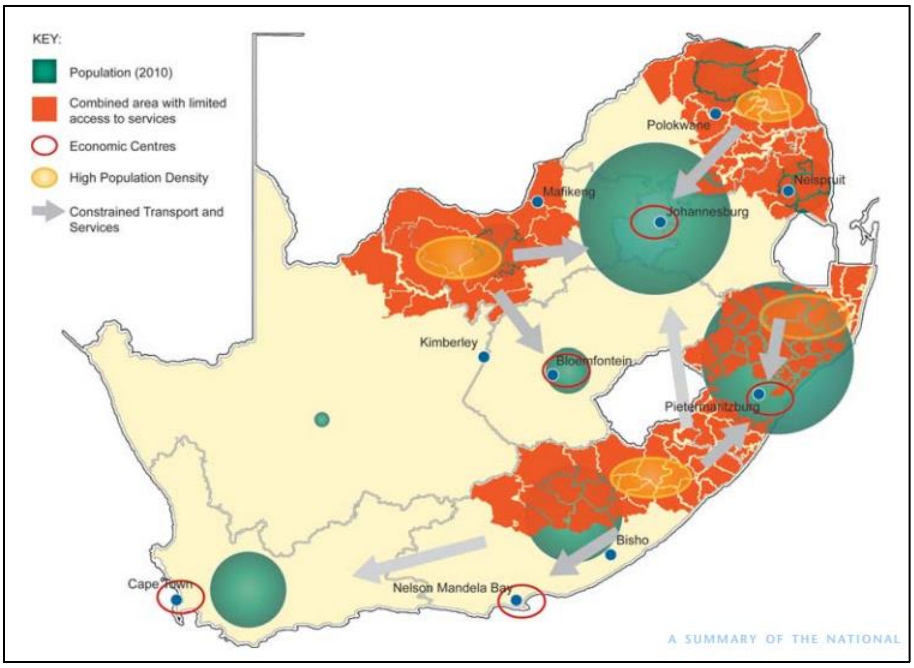

Figure 19 - Major cargo demand areas, Presidential Infrastructure Coordinating Commission (2013)

The two major metropolitan areas are connected via a rail corridor, namely Natcor. The rail network is approximately 730 km of double track (Porée, 2011). Porèe (2011) stated that the Natcor corridor had a capacity of 45 mil tons per year, but actual throughput varied between 8-10 mil tons per year. The route is usually served by 50 x 40 ton wagons, which surmounts to about 2000-3000 tons per train. The trains run at average speeds of 40-60 km/h and thus the travel time for cargo is around 12-14 hours.

Figure 20 below shows the Natcor rail network (orange line) that runs between the POD and Gauteng:

Figure 20 - Natcor Rail Corridor, Transnet Group Planning (2009)

The cargo is also moved to Gauteng via road transport. The total length is around 580 km along the N3 corridor, and the freight totalled approximately 42 mil tons in 2007 (Porèe, 2011). The freight trucks achieve an average of approximately 60 km/h and thus take around 10 hours to make the trip.

Along with the Natcor rail line that runs to Gauteng, the port is served by another large rail line. The line is known as the North Coast Line and links the POD with Richards Bay and the northern and eastern interior.

Regional highways connect the port to other parts of the country. The N2 highway is a six lane dual carriageway which connects Cape Town to Richards Bay and beyond. The port is connected to the N2 and N3 via the Edwin Swales freeway. It is an eight-lane dual carriageway freeway and provides a crucial link between the main freight highways and the POD.

Chapter 3

Durban Container Terminal throughput and capacity analysis

This chapter analyses the DCT container throughput history for the last 10 years along with various projections for future container throughput volumes for the future. This chapter then aims to calculate the current capacity of the DCT (expressed in TEU moves/year), by determining which constraint was limiting the capacity of the terminal. The methods are explained in Section 2.3. This chapter will give an indication if the DCT needs to expand in the next couple of years.

3.1 Container Throughput history of DCT

To understand the future growth of the container trade for the DCT, it was decided to investigate and understand the container throughput history of the port. This will provide background for making projections for the container throughput levels in the future, as well as giving an indication of the reaction on container trade during difficult economic circumstances.

The container throughput volumes were obtained from Nandkuar (2016) for the last ten years. The data reflects the total TEU throughput for the DCT and can be seen in Table 4.

Table 5 – Durban Container Terminal throughput history, Nandkuar (2016)

Year	TEUs
2005	1 898 483
2006	2 202 841
2007	2 480 223
2008	2 642 558
2009	2 384 879
2010	2 529 209
2011	2 720 915
2012	2 568 124
2013	2 632 515
2014	2 664 330
2015	2 770 335

As seen in Table 4 the container throughput for the DCT has been increasing over the past 10 years. Figure 21 below represents the throughput data graphically and shows certain trends in the container trade which is explained below:

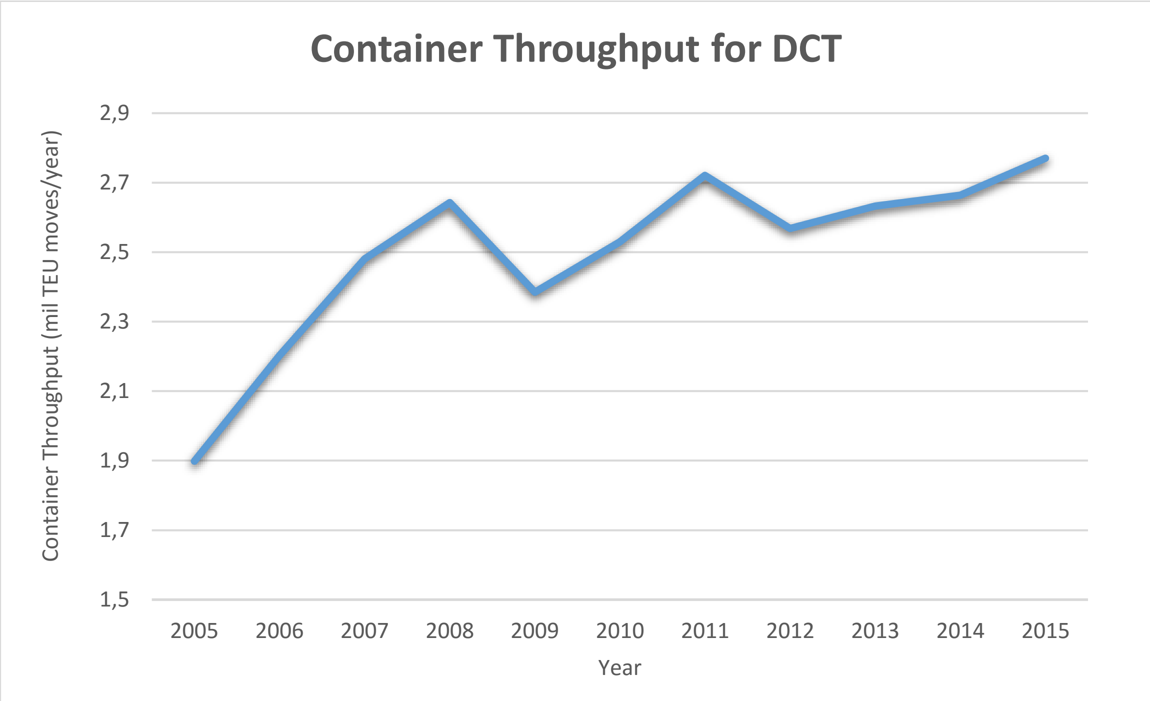

Figure 21- Durban Container Terminal throughput (combined Pier 1 and Pier 2), Adapted from Nandkuar (2016)

Figure 21 shows the container throughput volumes for the DCT from 2005 to 2015. The terminal experienced steady growth until the start of 2009. At that point a global recession was experienced which saw the decline in container volumes for that year. Once the markets recovered the container industry started rebuilding. The annual container throughput volumes grew by an average of 4.6% per year, from 2005 and 2015. There was a rise in container volumes from around 2.5 to 2.7 million TEU moves/year between 2010 and 2015.

3.2 Capacity of Durban Container Terminal

This section aims to calculate the overall capacity of the DCT. This capacity is expressed in TEU moves/year, and is the lesser of the berth capacity and the container stacking yard capacity. These two capacities are critical and limit the overall capacity of a container terminal, and are indicated by the red boxes in Figure 22. The constraints that are shown in the green boxes below are constraints which are variable and much easier to increase. These capacities have been calculated and are shown in Appendix B.3.

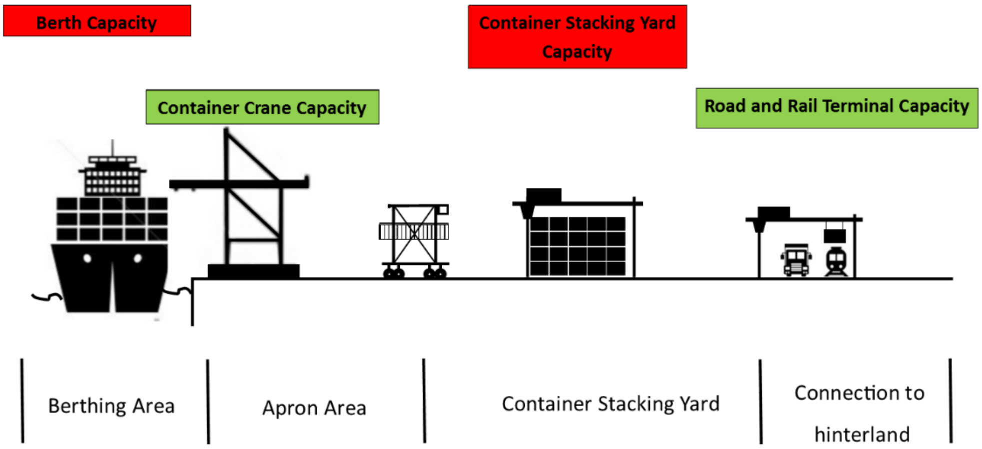

Figure 22 - Capacity limiting constraints for container terminals

3.2.1 Characteristics of the DCT

To calculate the above-mentioned critical capacity limiting constraints the characteristics of the DCT are required. **Error! Reference source not found.** shows the layout of the DCT. The

DCT is divided into two container terminals, Pier 1 and Pier 2, which both contribute to the overall capacity of the DCT. Figure 23 shows the berth layout of the DCT.

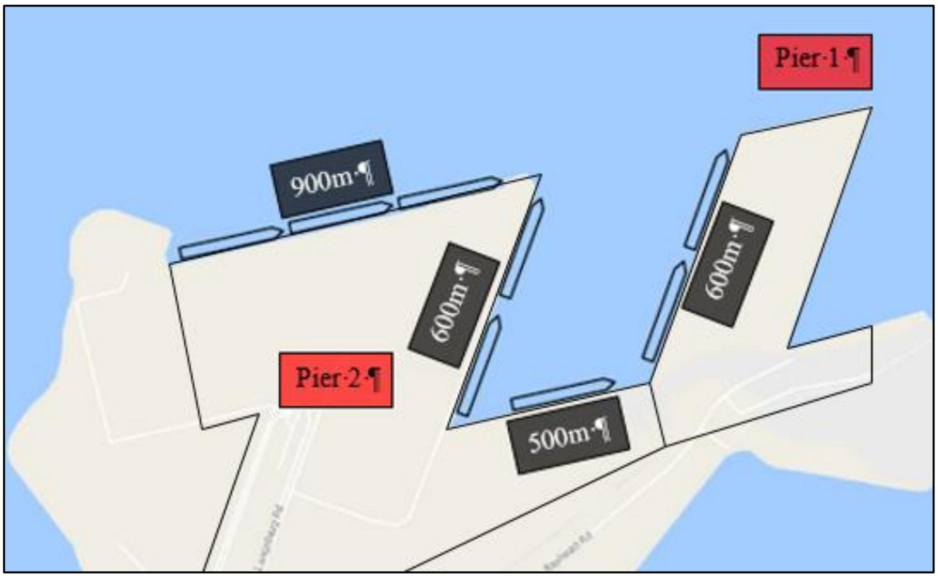

Figure 23 - Layout of DCT, adapted from Google Maps (2016)

Table 6 shows the characteristics for the DCT that were used in the capacity calculations.

Table 6 - Characteristics of DCT

Characteristic	***Pier 1***	***Pier 2***	***Source***
Peak factor	1.1	1.1	See Appendix B.2
Number of berths	2	6	See Figure 22
Berth lengths(m)	600	2000	See Figure 27
Berth Occupancy (%)	50	50	Assumption – see note (a) below
Crane productivity	25	25	Assumption – see note (b) below
TEU factor	1.6	1.6	Transnet Limited (2015)
Number of groundslots	4000	16274	See note (c) below
Stacking system	RTG	Straddle Carrier	
Max effective stacking height	5	3	
Dwell time (days)	5	5	Assumption – see note (d) below
Transhipment (%)	15	15	See Appendix B.1
Operational hours per year	8760	8760	Assumption – see note (e) below

NOTE: a – Researcher assumed value based on average berth occupancy of modern-day container terminals.

b - Crane productivity that the DCT should be achieving. Transnet (2015) stated values of 22.2 and 24 container moves/h, which is not sufficient for a modern-day terminal. It is recommended that the port increase the productivity to keep up with growing demand.

c – Pier 2 ground slots were stated by Moonsamy (2016). Pier 1 groundslots were calculated via aerial image, Google Earth (2016).

d – Transnet Limited (2015) stated a dwell time of 3.5 days, which was assumed as implausible by the researcher, thus a more realistic dwell time of 5 days was used for calculations.

e - Calculated as 24 hours a day, 7 days a week = 24*365 = 8760 hours

The subsequent section will calculate the berth capacity shown in Figure 22.

3.2.2 Berth Capacity

The berth capacity was calculated using two formulas which were outlined in Section 2.3.

Ligteringen Method

This method was calculated using the formula proposed by Ligteringen and Velsink (2012) as follows:

$$Cb = p \times f \times Nb \times tn \times mb$$

Equation 5

Where: Cb = average annual number of TEU per berth (TEU/yr)

p = gross production per crane (moves/hr)

f = TEU factor

Nb = number of cranes per berth – **assumed as 3.5** for modern day container terminals

tn = number of operational hours per year (hours/yr)

mb = berth occupancy factor (%)

The values used for the above formula are stated in Table 7.

Table 7 - Berth Capacity Calculation (Ligteringen)

Characteristic	***Pier 1***	***Pier 2***
Gross Crane Productivity (p)	25	25
TEU Factor (f)	1.6	1.6
Number of cranes/berth (Nb)	3.5	3.5
Operational Hours/year (tn)	8760	8760
Operational Berth Occupancy	0.5	0.5
Average Annual TEU/berth	613 200	613 200
Number of berths	2	6
Average Total TEU moves/year	**1 226 400**	**3 679 200**

The Bestenbreur method

Bestenbreur (2016) stated a rule of thumb used in the calculations of berth capacity as the following:

- 125 000 Container moves / 100m of available quay length
- 1 Container Crane for every 100m of quay side length

The above assumption is based on a crane productivity of 25 container moves/hour, whereby Pier 1 achieved 22.2 Cont. moves/hour, and Pier 2 achieved 24 container moves/hour. The assumption was used due to the DCT achieving a low crane productivity, compared to modern day ports, and should strive to achieve 25 container moves/hour.

The berth capacity was represented in TEU moves/year and can be seen in

Table 8

Table 8 - Berth Capacity for Durban Container Terminal, Bestenbreur (2016)

Characteristic	***Pier 1***	***Pier 2***	***Units***
Total quayside length	600	2000	m
Assumption	125 000 Cont. moves/100m quay length	125 000 Cont. moves/100m quay length	

Throughput through quay	750 000	2 500 000.00	Cont. moves/year
TEU Factor	1.60	1.60	
Berth Capacity	**1 200 000**	**4 000 000**	**TEU moves/year**

Summary of Berth Capacity

Two calculations were performed to obtain the throughput that the quay lengths/berths could handle. The Ligteringen method follows the assumption that 3 cranes operate per berth, which has increased with modern day container terminals, thus 3.5 cranes per berth was used for calculations. The two methods used to obtain the berth capacity are summarised in Table 9.

Table 9 - Berth Capacities for DCT

Method	***Pier 1***	***Pier 2***	***Unit***
Ligteringin (3.5 cranes per berth)	1 226 400	3 679 200	TEU moves/year
Bestenbreur Rule of Thumb (125 000 Cont. moves/100m)	1 200 000	4 000 000	TEU moves/year

The data above was graphically presented and can be seen in Figure 24.

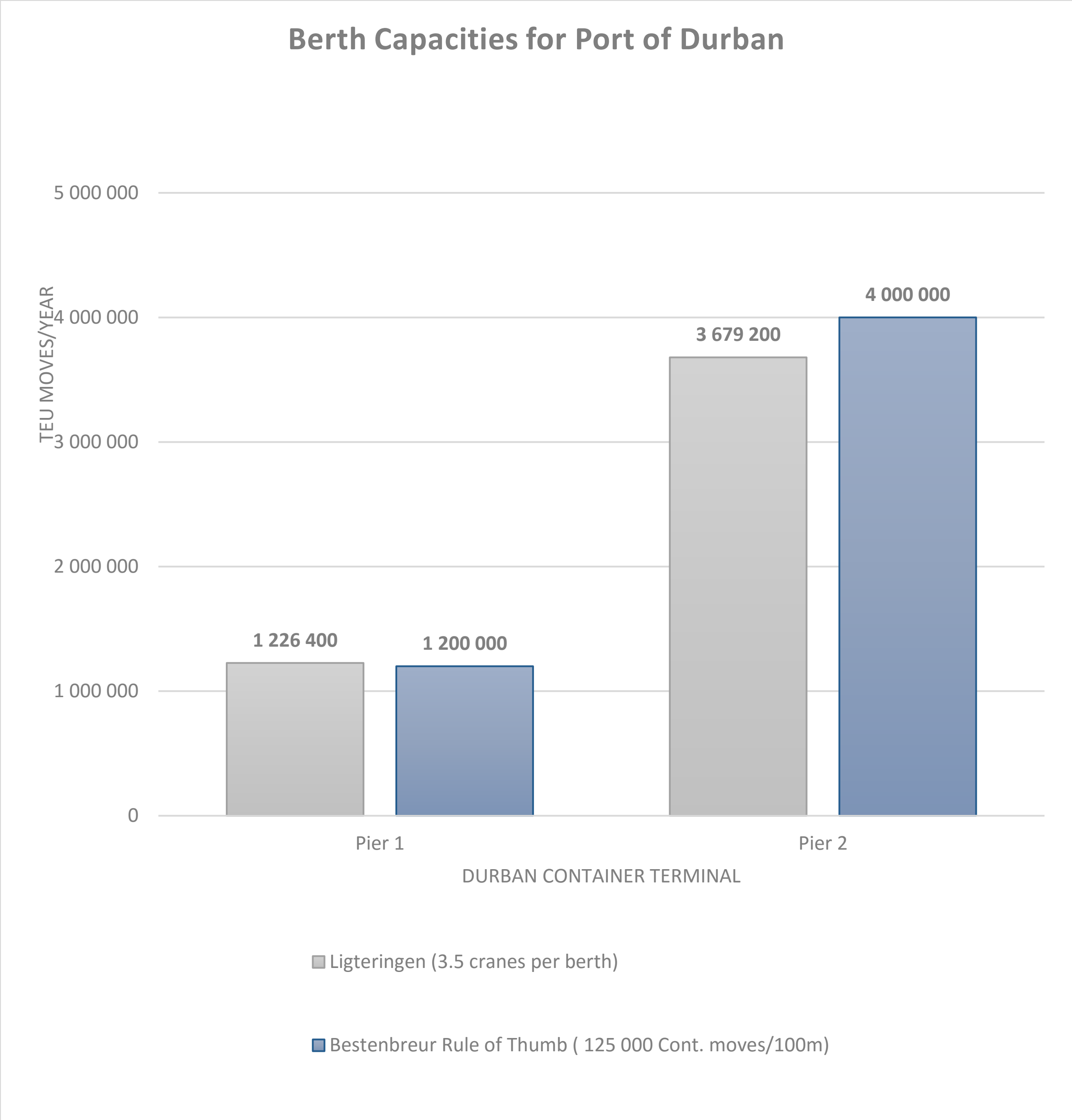

Figure 24 - Berth Capacity for DCT

Figure 24 shows that both methods to calculate the berth capacity return similar values. The Bestenbreur method will be used to represent the berth capacity as the calculation represents an optimal berth situation, which the DCT should be achieving. The subsequent section will calculate the container stacking yard capacity, using the formulas set out in Section 2.3.

3.2.3 Container Yard Stack throughput

The capacity of the container stack yard was calculated using formulas adapted from Bestenbreur (2015). The input parameters can be seen in Table 10. The method equates the operational container yard inventory to the effective inventory that the container stack can provide. The two equations can be seen below:

$$\begin{pmatrix} Max\ Operational \\ CY\ Inventory \\ TEU \end{pmatrix} = \left(\frac{Qdi + Qlo}{365}\right) \times \left(\frac{1 - \frac{1}{2}Tr\%}{100\%}\right) \times PF \times TEUfactor \times Dwell\ time$$

Equation 6

$$=$$

$$\begin{pmatrix} Max\ Effective \\ CY\ Inventory\ (TEU) \end{pmatrix} = \begin{pmatrix} Available \\ no. of \\ CY\ groundslots \end{pmatrix} \times \begin{pmatrix} Max\ effective \\ stacking\ height \end{pmatrix} \times n1 \times n2 \times n3$$

Equation 7

It was required to work out the total number of moves that the container stack yard can generate. This is represented by Qdi + Qlo above, and can be seen in Equation 8:

$$(Qdi + Qlo) = \frac{\begin{pmatrix} Available \\ no. of \\ CY\ groundslots \end{pmatrix} \times \begin{pmatrix} Max\ effectie \\ stacking\ height \end{pmatrix} \times n1 \times n2 \times n3}{\left(\frac{1 - \frac{1}{2}Tr\%}{100\%}\right) \times PF \times TEUfactor \times Dwell\ time \times \frac{1}{365}}$$

Equation 8

the container stacking yard.

Table 10 shows the variables used to calculate the capacity of the container stacking yard.

Table 10 – Throughput generated by container stack

Characteristic	***Unit***	***Pier 1***	***Pier 2***	***Source***
Transhipment	%	15	15	See Appendix B.1
PF- Peak factor	-	1.1	1.1	See Appendix B.2
TEU Factor	-	1.6	1.6	See note (a) below
Dwell time	days	5	5	See note (b)
Available no. groundslots – see Table 6	-	4000	16274	See note (c)
Max. effective stacking height	Containers	5	3	See Section 2.3.2
Average stacking height	Containers	3.5	2.5	
n1 = Average stacking height/Max. Effective stacking height	-	0.7	0.83	
n3 = Ground slots Utilized/Ground slots available	-	0.9	0.95	
n2 = Peak average stacking height/average stacking height		1.0	1.0	
Q(di) + Q(lo)	Cont. moves/year	560 344	1 711 991	
Equivalent Container Stacking Yard Capacity	**TEU moves/year**	**896 550**	**2 739 185**	

Where:

a) Assumption by the researcher. Most modern-day terminals have a TEU factor between 1.5 and 1.7.

b) Transnet Limited (2015) stated a dwell time of 3.5 days, which was assumed as implausible by the researcher, thus a more realistic dwell time of 5 days was used for calculations.

c) Pier 2 ground slots were stated by Moonsamy (2016). Pier 1 groundslots were calculated via aerial image, Google Earth (2016).

3.2.4 Analysis of results

This section will draw a comparison between the two critical capacity limiting constraints of the DCT. This will provide a clear indication of the capacity of the DCT, and which constraint is limiting the maximum capacity of the terminal.

The above-mentioned throughputs are summarized in Table 11 below:

Table 11 - Comparison of throughput constraints

Constraint	***Pier 1***	***Pier 2***
Berth Capacity – Ligteringen (not shown in Figure)	1 226 400	3 679 200
Berth Capacity - Bestenbreur	1 200 000	4 000 000
Container stacking yard capacity - Bestenbreur	896 550	2 739 185

The data from Table 11 is represented visually in Figure 25.

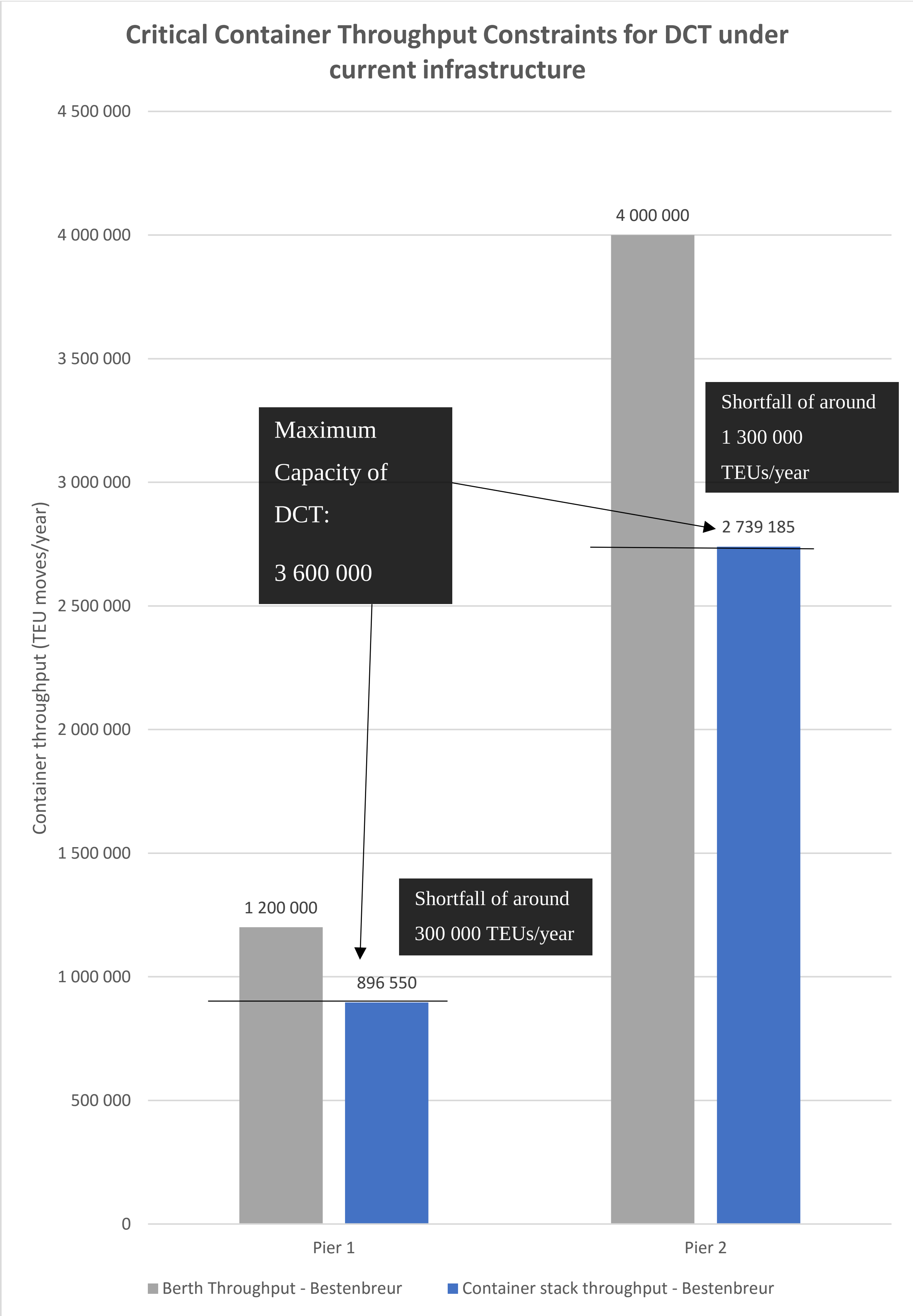

Figure 25 - Capacity Constraints for Durban Container Terminal

3.2.5 Conclusion

The purpose of this section was to calculate the capacity of the DCT and to identify the capacity limiting constraint(s) for the terminal, with the current port infrastructure. Figure 25 was analysed and led to the following conclusions:

- **PIER 1:**
  - The **capacity limiting constraint for Pier 1** was the equivalent **container stacking yard capacity**
  - There was a shortfall of 300 000 between the berth capacity and the container stacking yard capacity
  - Chapter 4 will analyse the effect of the planned expansions on the two critical capacities, and conclusions will be drawn as to which constraint will limit container throughput in the future for the DCT.

- **PIER 2**:
  - The **capacity limiting constraints for Pier 2** was also found to be the **container stacking yard capacity**
  - There was a shortfall of 1 300 000 between the berth capacity and the container stacking yard capacity
  - To increase the maximum capacity of the DCT, the container stacking yard capacity would have to be increased. This can be achieved via expansions or upgrading the container stack system to an RTG and shuttle carrier system, which will be investigated in Section 5.1

Table 12 shows the capacity constraints for the DCT:

Table 12 - Capacity Constraints for DCT, current infrastructure

	Pier 1	***Pier 2***	***Combined (DCT)***
Berth Capacityt (TEU moves/year)	1 200 000	4 000 000	5 200 000
Container Stack Throughput (TEU moves/year)	900 000	2 700 000	3 600 000
Shortfall (TEU moves/year)	300 000	1 300 000	1 600 000

The **maximum capacity of the DCT** was calculated to be around **3 600 000 TEU moves/year**.

The **total shortfall** between the **berthing capacity** and the **container stacking yard capacity** was **1 600 000 TEU moves/year**. For the DCT to operate at the optimal level, the container stacking yard capacity would have to be increased to match the berth capacity.

3.3 Container Throughput Projections vs Current Capacity of DCT

To make accurate projections for the container throughput for the DCT, a few methods were analysed. Forecasting container volumes has proven to be a complex task, due to the wide range of influential factors that play a part in the throughput for a port. Due to the complexity of predicting container volumes, the following methods of predictions were investigated:

- A forecast done by the researcher by implying a constant 3% growth rate (refer to Appendix A.2). This forecast was used to create a lower limit of growth for the DCT. The container volumes of the DCT grew with an average of 4.5% between 2005 and 2015 – Section 3.1.
- A forecast done by the researcher by implying a constant 5% growth rate (refer to Appendix A.2). This forecast was used to create an upper limit of growth.
- A forecast done by the researcher based on monthly container volumes for the DCT (refer to Appendix A.1). This forecast provides a projection of actual throughput data by acquiring a formula to fit the historic data, which provides an accurate projection of throughput volumes for the future.

The results of the container throughput projections were compared and are shown in Figure 26. The capacity of the DCT, calculated in the previous section, is also shown in Figure 26. This figure aims to show when the DCT will reach its maximum capacity under the current infrastructure.

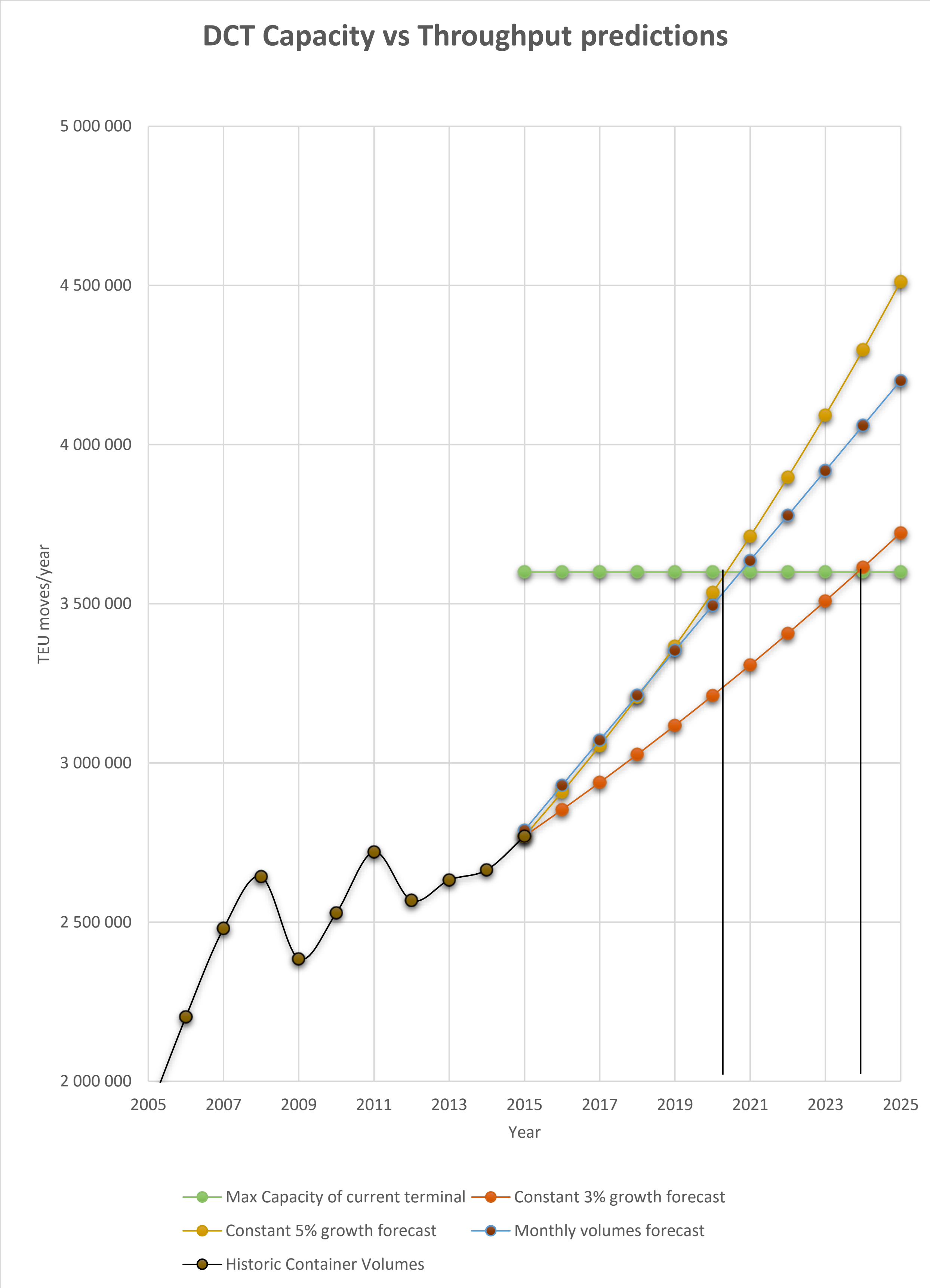

Figure 26 - DCT Capacity vs Container volume projections

The following conclusions about the container throughput projections were made:

- The growth has slowed down in the year 2016 due to slow economic growth, but is predicted to continue to grow in the next few years, based on historical trends.
- The DCT will reach its maximum capacity between 2020 and 2024 under the current infrastructure, per the container growth projections.
- The DCT should find a solution to increase the capacity of the DCT. This study will investigate these solutions in Section 7.
- Expansion is crucial for the DCT to development to meet future demand.

The next chapter of this report aims to identify future expansion projects for the DCT, and to calculate the effect that these expansions have on the maximum capacity of the DCT.

Chapter 4

Proposed Expansions to DCT and effect on capacity

This section identifies the expansion plans for the DCT for the next 20 years. The effect that the expansions will have on the maximum capacity of the DCT is calculated and presented. This section then compares this capacity to the projected container throughput volumes as outlined in Section 3.3.

4.1 Proposed expansions

The DCT is currently the largest container terminal in South Africa. Transnet, the national ports authority, has laid out a three-phase plan of expansion and development of the Port of Durban (POD). The three phases have been defined as the short, medium and long-term layouts. The expansion of the DCT is included in this plan and will be outlined in this section of the report.

Figure 27 shows the current layout of the POD:

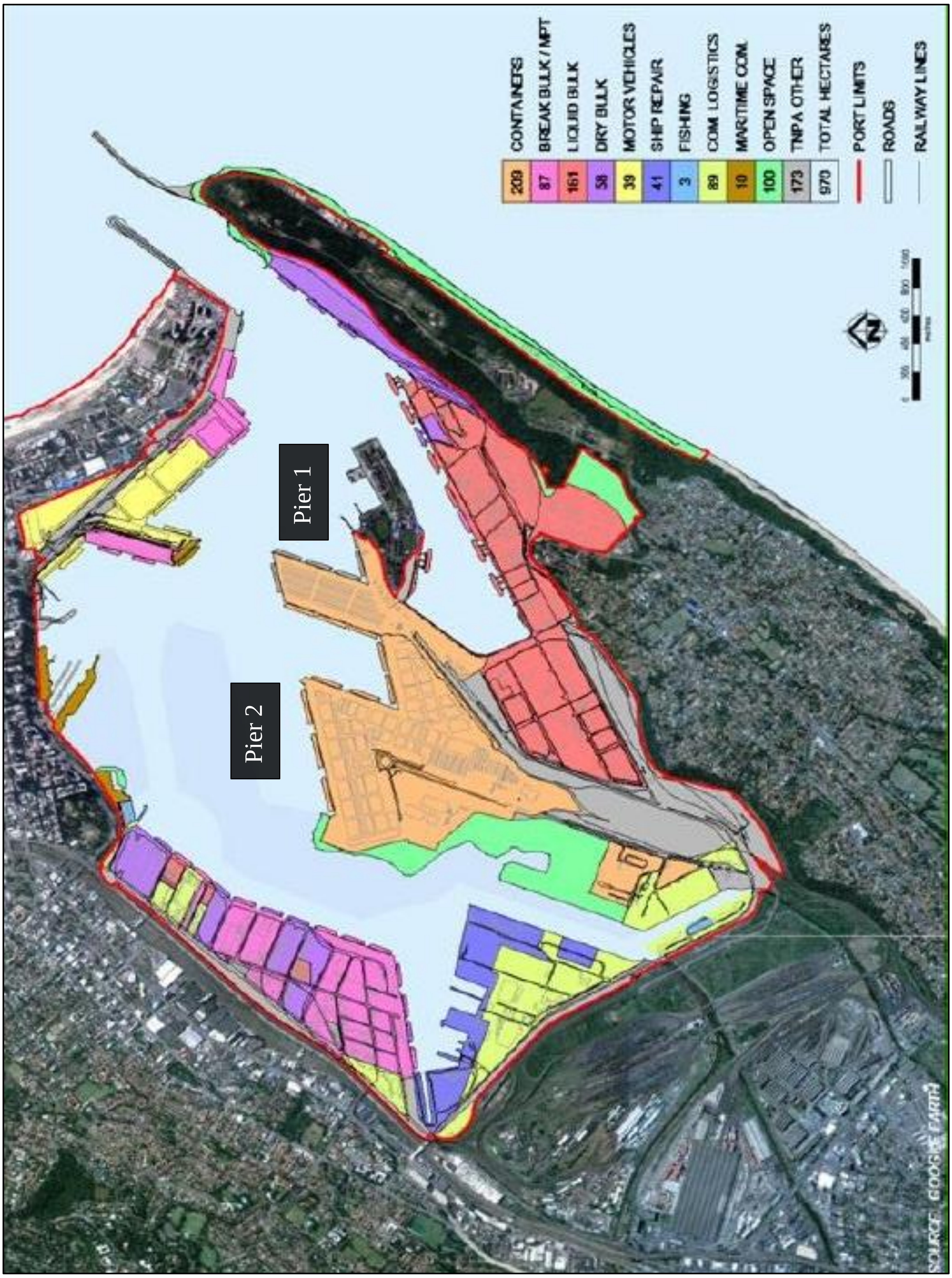

Figure 27 - Current layout of the POD, Transnet (2014)

4.1.1 Short-term layout

This phase involves lengthening, deepening and widening the berths north of Pier 2 which will provide the first deep water container berths in Durban. The north quay of Pier 2 will be lengthened by 270m. This phase also incorporates absorbing the rail south of Bayhead Road into the terminal, with 52ha used for back-of port logistics. Further the expansion plans involve rationalisation of the landside terminal to increase stacking areas and operational efficiencies.

Figure 28 shows the layout of the short-term expansion plans:

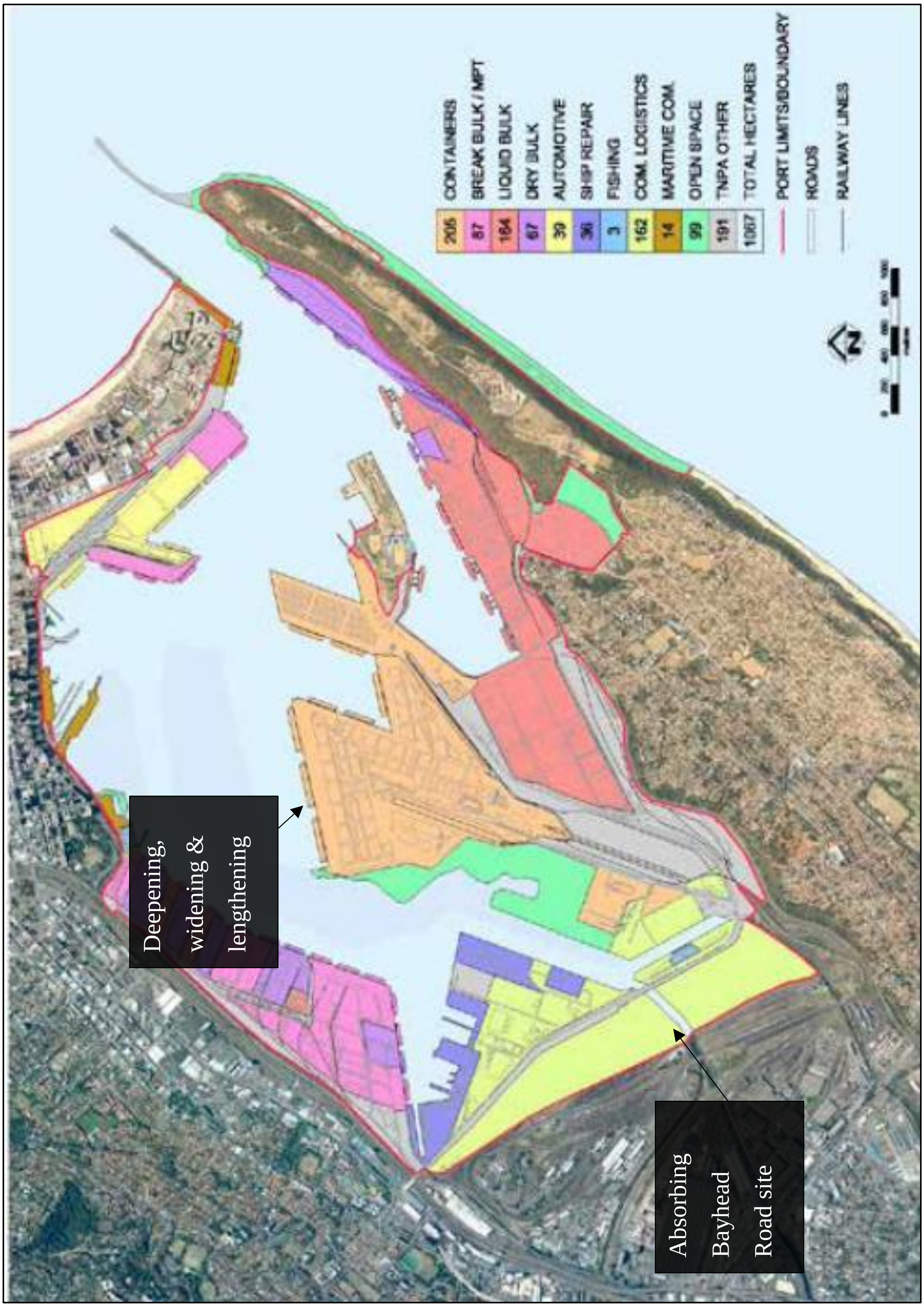

Figure 28 - Short-term layout of POD, Transnet (2014)

4.1.2 Medium-term layout

This expansion plan aims at increasing the capacity of the DCT. It involves the reclamation of land at the Salisbury Island, which will increase the overall area of Pier 1. The project must be preceded by the rationalisation of the SA Naval Base onto a smaller footprint. It was estimated that the expansion would add an additional 6292 ground slots – see Section 4.2.1.2. While the construction of the Durban Dig-Out Port has been put on hold, Transnet (2014) stated that the medium-term development would involve strategical planning to increase the capacity of the DCT.

Figure 29 shows the medium-term layout of the POD:

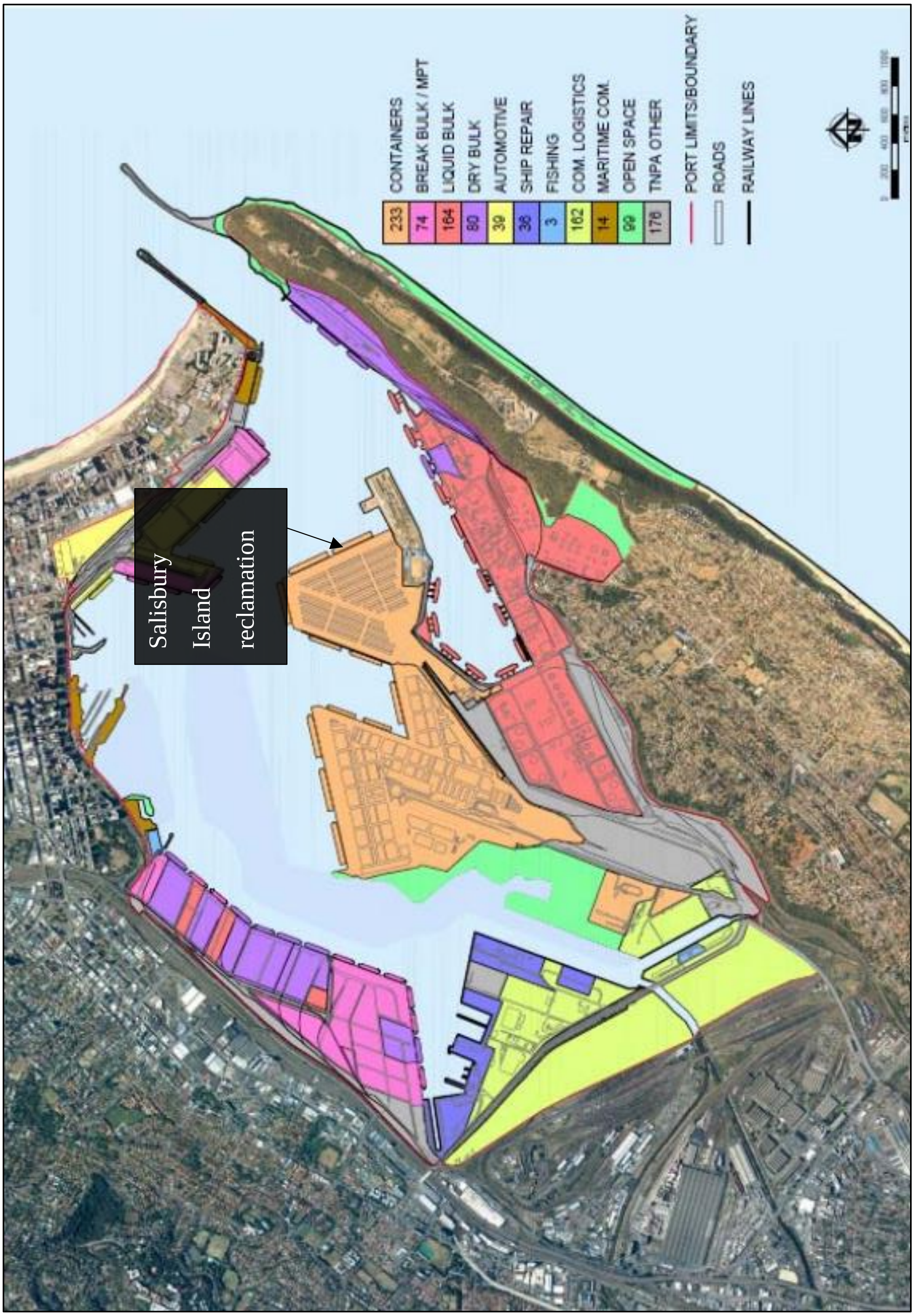

Figure 29 - Medium-term layout for expansion of POD, Transnet (2014)

4.1.3 Long-term layout

The long-term potential plan for the POD shows a fully developed port within the special limitations of the bay. The expansion of the Bayhead commercial logistics area results in an additional 308ha of land. The existing arrival and departure yards would have to be relocated and the lines connecting the port to the main line would have to be realigned.

The long-term layout plan set out by Transnet (2014) includes the development of the DDoP at the location of the old airport site, which could change as the concept of the DDoP has been put on hold.

Figure 30 shows the long-term layout set out by Transnet (2014). The long-term layout is set to be achieved by 2040. The main characteristic that should be noted is the use of the land south of Bayhead Road as a functional logistics hub:

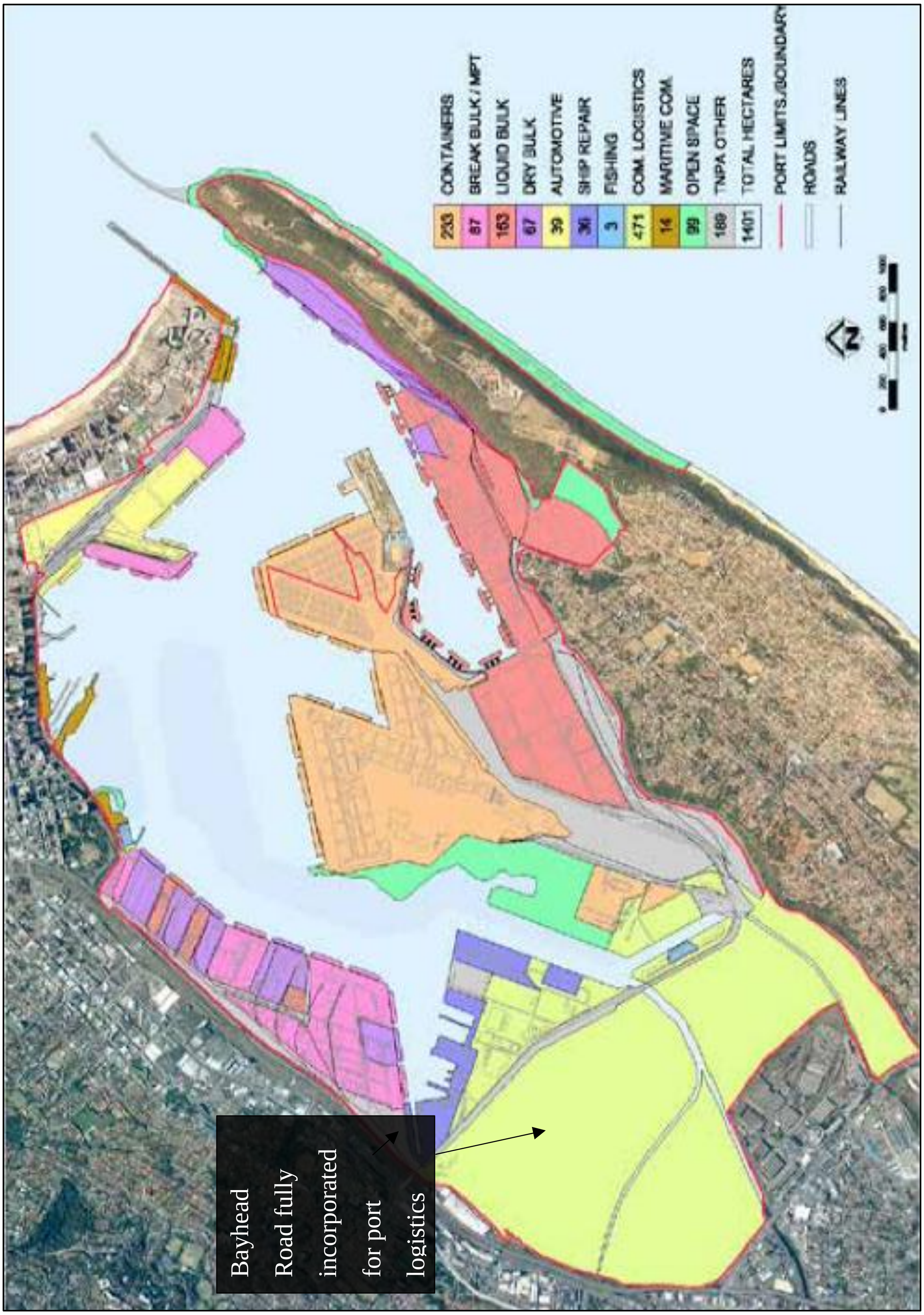

Figure 30 - Long-term layout of POD, Transnet (2014)

4.2 Effect of port expansions on capacity

This section aims to identify the effect that the planned port expansions would have on the berth capacity and the container stacking yard capacity. This section will be split into two subsections for Pier 1 and Pier 2 respectively. Each subsection will analyse the latest planned expansions and the impact that it has on the above-mentioned capacity constraints.

Section 4.1 outlined the following two expansion projects which effect the capacity of the DCT: (1) Berth lengthening, deepening and widening of Pier 2; (2) Salisbury Island reclamation.

Figure 31 shows the proposed expansions to increase the capacity of the DCT.

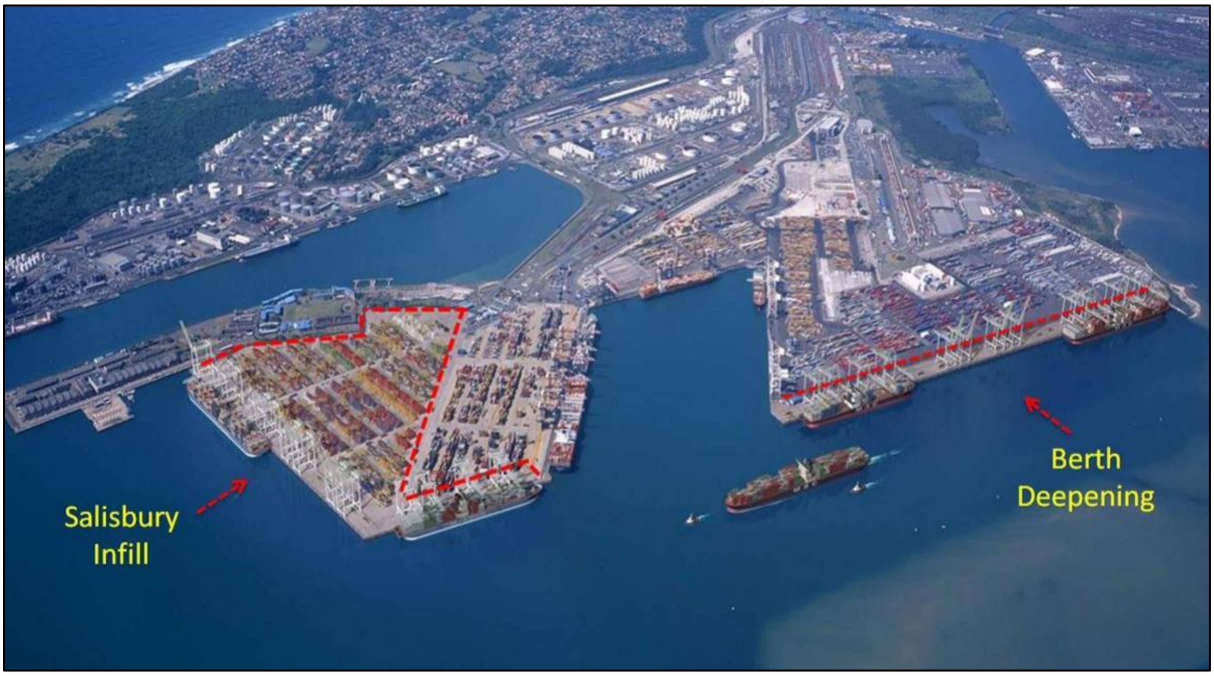

Figure 31 - Planned Port Expansions, TNPA (2015)

4.2.1 Pier 1 Expansions

As discussed in Section 4.1, Transnet plans to upgrade the Durban Container Terminal Pier 1, which is expected to begin in 2018. The main expansion to the terminal is known as the "Salisbury Infill", or the "Pier 1 Phase 2 Infill project", which involves the reclamation of land between the eastern corner of Pier 1 and Salisbury Island, which would provide a large area for a container stacking yard, and would provide Pier 1 with two additional berths.

4.2.1.1 Effect on Berth capacity

The planned expansion will increase the total amount of quayside length by 700m which will provide an additional 2 berths to the terminal. Figure 32 shows the change in berth length and number of berths for Pier 1:

Figure 32 - Berth Layout for Pier 1 after expansions

With the information shown in Figure 32 the new berth capacities can be calculated in the same way as Section 3.2.1. Firstly, the method proposed by Ligteringen and Velsink (2012) was used and can be seen in Table 13.

Table 13 - Ligteringen Berth Capacity

Characteristic	***Pier 1 Current***	***Pier 1 Expanded***
Gross Crane Productivity (p)	25	25
TEU Factor (f)	1.6	1.6
Number of cranes/berth (Nb)	3.5	3.5
Operational Hours/year (tn)	8760	8760
Berth Occupancy	0.5	0.5
Average Annual TEU/berth	613 200	613 200
Number of berths	2	4
Average Total Capacity (TEU moves/year)	**1 226 400**	**2 452 800**

.

Table 13 shows that the proposed expansion greatly increases the berth capacity. This was due to the above calculation having the container throughput as a function of the number of berths. The proposed expansion would double the number of berths available for container activities.

The Rule of Thumb method proposed by Bestenbreur (2016) is a function of the quay length. The quay length of the expanded terminal was calculated by taking the total current berth length, and adding the difference in quay length of the new berthing area. For this calculation, the Rule of Thumb method assumes 125 000 Cont. moves/100m quay length.

Table 14 shows the capacity change due to the proposed expansions – see Section 3.2.2

Table 14 - Bestenbreur (2016) Rule of Thumb

Characteristic	***Pier 1 Current***	***Pier 1 Expanded***
Total quayside length (m)	600	1300
Throughput through quay (cont. moves/year)	750 000	1 625 000
TEU Factor	1.60	1.6
Berth Capacity (TEU moves/year)	**1 200 000**	**2 600 000**

From the calculation in

Table 14 it was found that the expansions significantly increase the berth capacity. This increase was due to the increase in quay length and the addition of two berths for container related activity.

The changes in berth capacity can be seen in Figure 33.

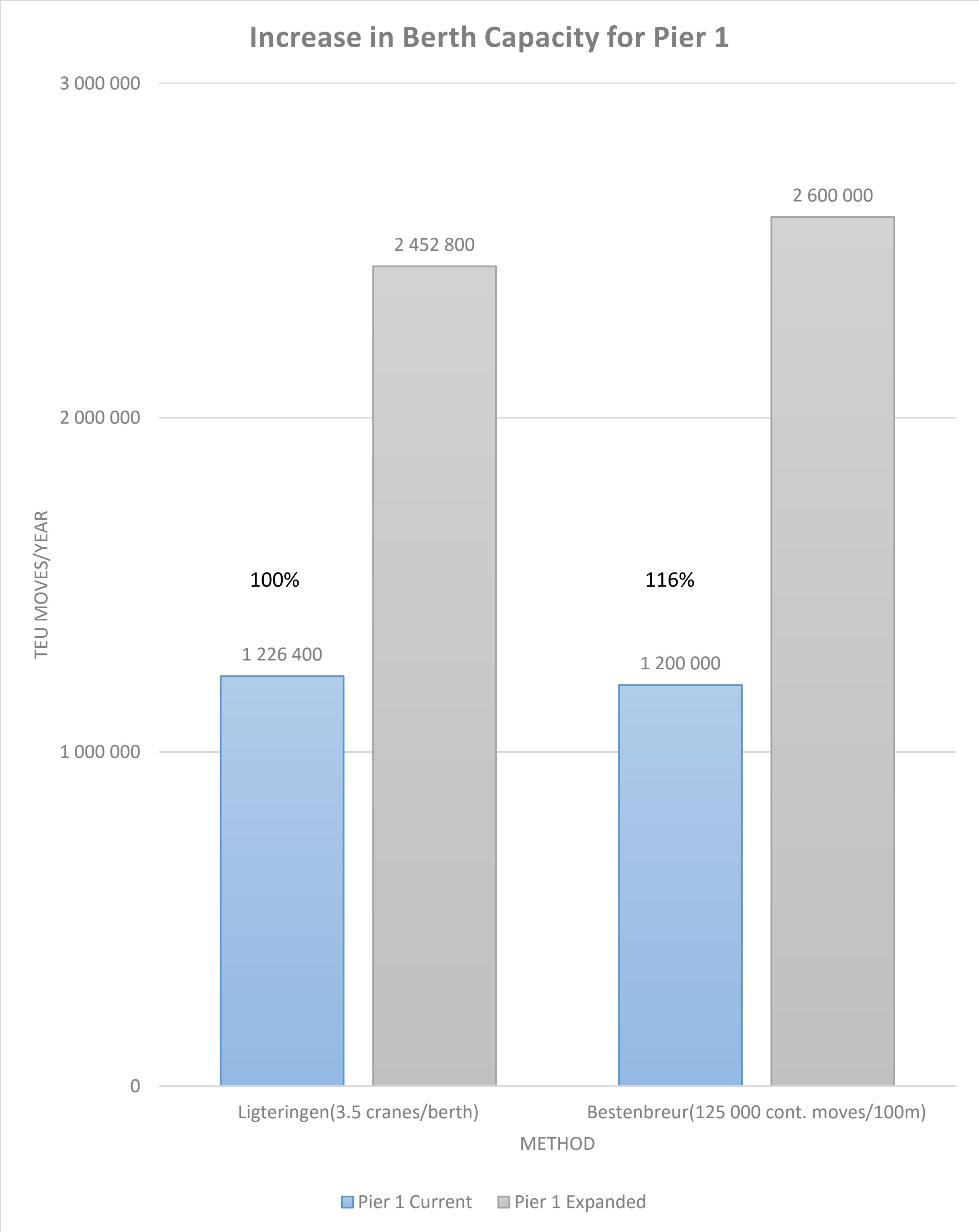

Figure 33 - Berth Capacity increase due to expansion.

Figure 33 shows that the throughput generated by the berths increased by over 100% for both methods. These constraints will be compared with the capacity of the container stacking yards after expansions have taken place. This will provide the maximum capacity of the DCT after the proposed are complete.

4.2.1.2 Effect on Container Yard Capacity

The number of ground slots that would be created on the Salisbury Infill was calculated using an area relationship with Pier 1. This was assumed accurate due to the container stack yard for Salisbury Infill also using a RTG stacking system. The areas were taken from Google Earth (2016). The calculation can be seen in Table 15:

Table 15 - Calculation of number of ground slots, Salisbury Infill

Characteristic	***Pier 1***	***Salisbury Infill***
Ground slots	4000	X = 6292
Area	134,192 m^2	211 070 m^2

The variable X in Table 15, represents the number of additional ground slots created by the Salisbury Infill. The number **of ground slots on Salisbury Infill stack yard** was calculated as **6292.**

The container stacking yard capacity for Pier 1, after expansion, is shown in Table 16.

Table 16 - Container Yard Stack increase due to expansion

Characteristic	***Unit***	***Pier 1***	***Pier 1 Expanded***
Transhipment	%	15	15
PF- Peak factor	-	1,1	1,1
TEU Factor	-	1,6	1,6
Dwell time	days	5	5
Available no. groundslots	-	4000	10 292
Max. effective stacking height	Containers	5	5
Average stacking height	Containers	3,5	3,5
n1 = Average stacking height/Max. Effective stacking height	-	0,7	0,7
n3 = Ground slots Utilized/Ground slots available	-	0,9	0,9
n2 = Peak average stacking height/average stacking height		1.0	1.0
Q(di) + Q(lo)	Cont. moves/year	560 344	1 411 765
Container Stacking Yard Capacity	**TEU moves/year**	**896 550**	**2 306 824**

The information mentioned in Table 16 and can be seen graphically in Figure 34.

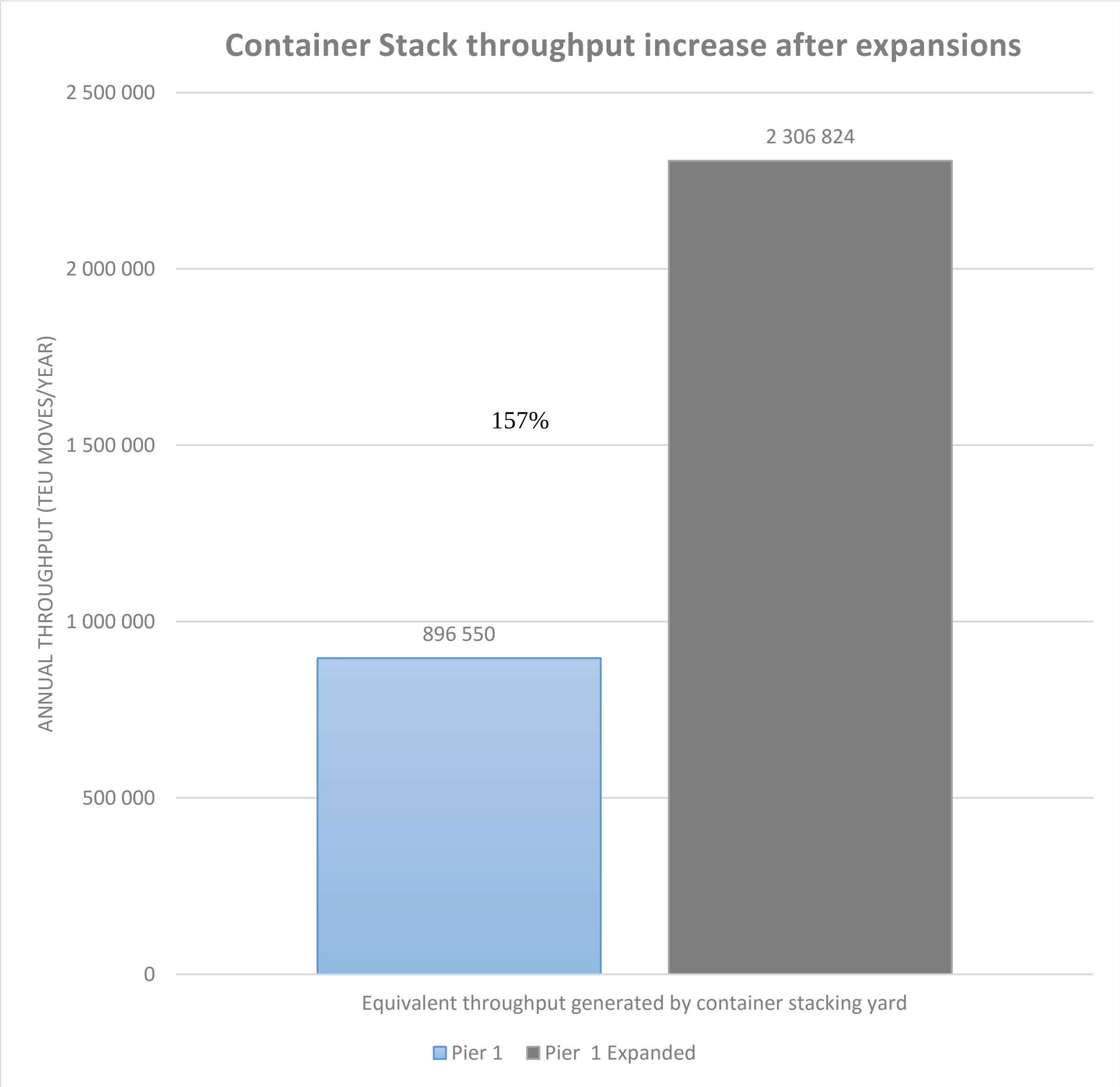

Figure 34 - Container Yard Stack Capacity increase for proposed expansion

Figure 34 shows that the Salisbury Infill expansion would have a great impact on the container yard stack capacity. The expansions were found to increase the overall container stack capacity by around 157%. This is due to the vast amount of container slots that would be added to the terminal.

The limiting factor for Pier 1, under current infrastructure was found to the container stack capacity, thus the Salisbury Infill is instrumental in the upgrading and development of the Durban Container Terminal.

4.2.2 Pier 2 Expansions

This project is referred to herein as "Pier 2 Berth lengthening and deepening", involves the lengthening and deepening of berths 203-205. The berths would gain 270m in length and be deepened from a draft of 12.8m to 16.5m to increase the vessel handling capabilities (Naidoo et al 2014). These expansions would enable the Durban Container Terminal to handle three 350m vessels simultaneously. The construction is set to begin in 2017 and be completed in 2022.

This section will analyse the effect that the above-mentioned expansions would have on the container handling capacities. Figure 35 shows the expansions to Pier 2.

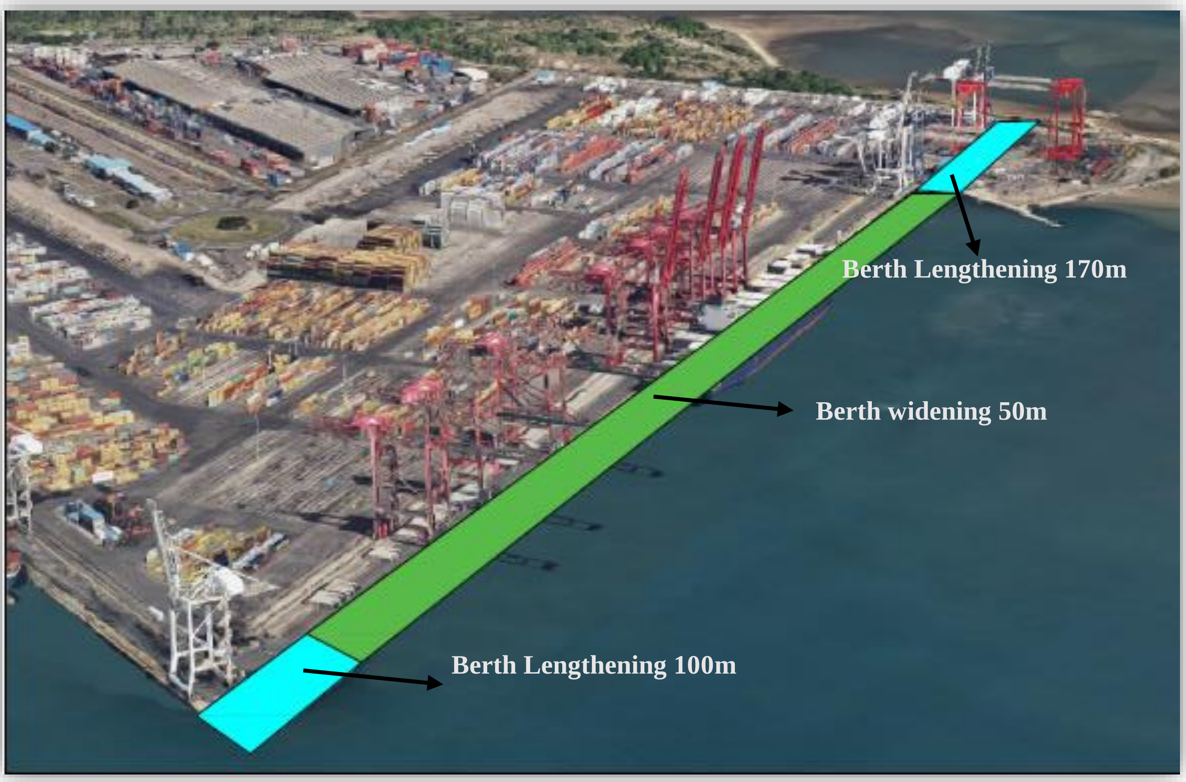

Figure 35 - Proposed expansions to Pier 2, adapted from Google Earth (2016)

4.2.2.1 Effect on Berth capacity

The Ligteringen and Velsink (2012) method is a function of the number of berths. The proposed expansion was set to lengthen the current berths by 270m in total, providing three 350m berths on the north part of Pier 2.

Table 17 below shows the calculation as per Ligteringen and Velsink (2012) to acquire the berth capacity once expansions have been complete.

Table 17 - Berth Capacity increase due expansion, Pier 2

Characteristic	***Pier 2***	***Pier 2 Expanded***
Gross Crane Productivity (p)	25	25
TEU Factor (f)	1.6	1.6
Number of cranes/berth (Nb)	3.5	3.5
Operational Hours/year (tn)	8760	8760
Berth Occupancy	0.5	0.5
Average Annual TEU/berth	613 200	613 200
Number of berths	6	6
Average Total TEU moves/year	**3 679 200**	**3 679 200**

The Ligteringen Method returned the same berth capacity as the current Pier 2. This was due to the method being a function of the number of berths, which does not get increased due to expansion.

The Rule of Thumb method stated by Bestenbreur (2016) was used to reassess the increase in berth capacity. This method is a function of the quay length; thus, a noticeable increase was expected. Table 18 shows the calculation for this increase:

Table 18 - Berth Capacity Increase Pier 2, Rule of Thumb method

Characteristic	***Pier 2***	***Pier 2 Expanded***
Total quayside length (m)	2000	2270
Throughput through quay (Cont. moves/year)	2 500 000.00	2 837 500.00
TEU Factor	1.60	1.60
Berth Capacity (TEU moves/year)	**4 000 000.00**	**4 540 000.00**

The above two calculations were represented graphically and the percentage increase was shown on the graph. Figure 36 shows the increase in berth capacity for Pier 2, as calculated with two methods stated above.

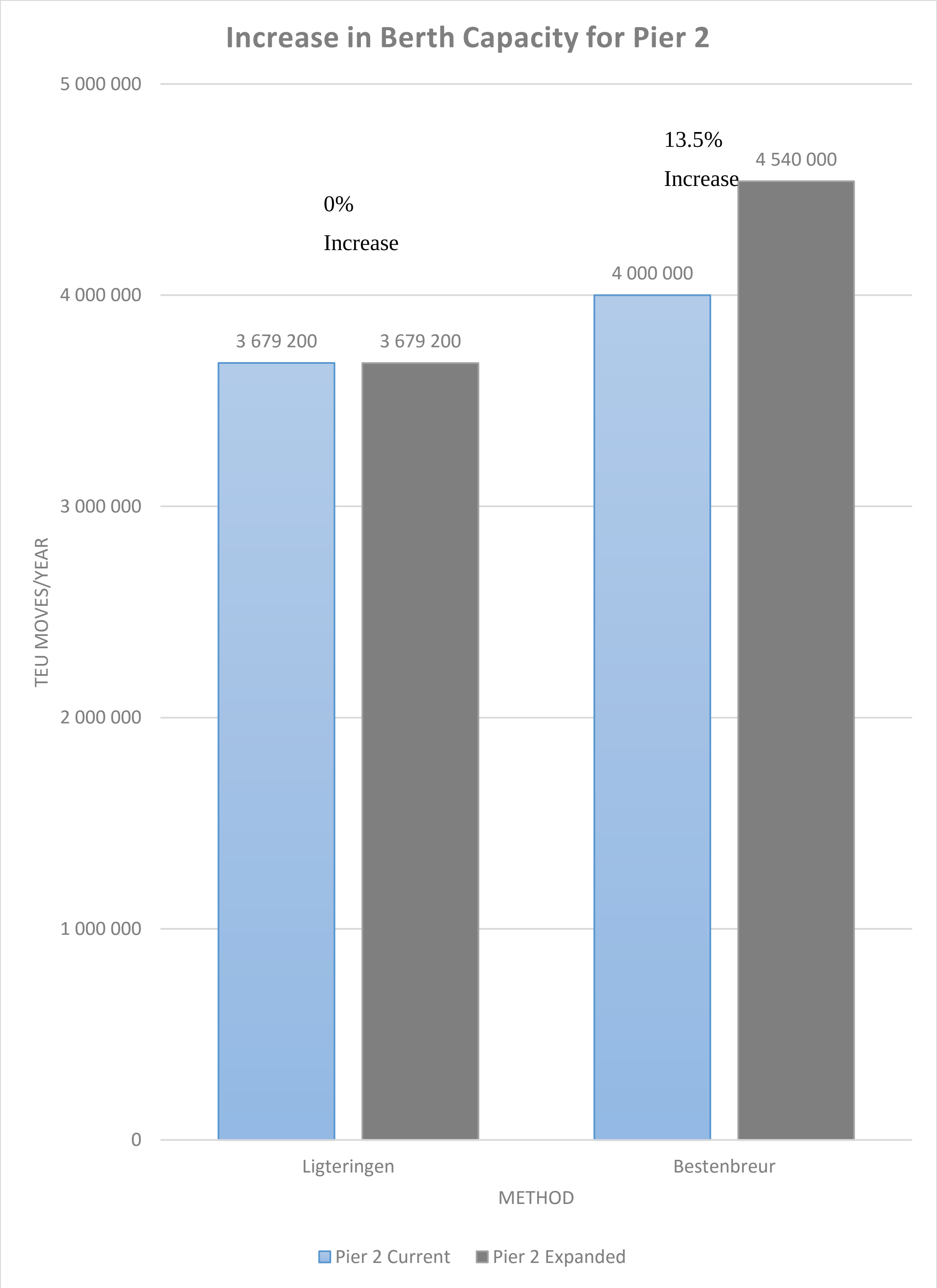

Figure 36 - Increase in Berth Capacity, Pier 2

The Bestenbreur method shows that the expansions on Pier 2 would increase the berth capacity by around 500 000 TEU moves/year. This was due to the additional 270m of quayside length that the expansions add.

4.2.2.2 Effect on Container Yard Capacity

The expansions on Pier 2 aim at lengthening, widening and deepening berths 203-205 to create 3x 350m berths, which will be deepened to handle larger vessels more frequently. The input variables to calculate the container yard stack capacity remain unchanged, except for the number of ground slots, due to the berths being extended by 50m.

The number of ground slots that would be added to the terminal was calculated using an aerial image, whereby the number of ground slots were added for each individual stack. Figure 37 shows the layout of the new container stacks.

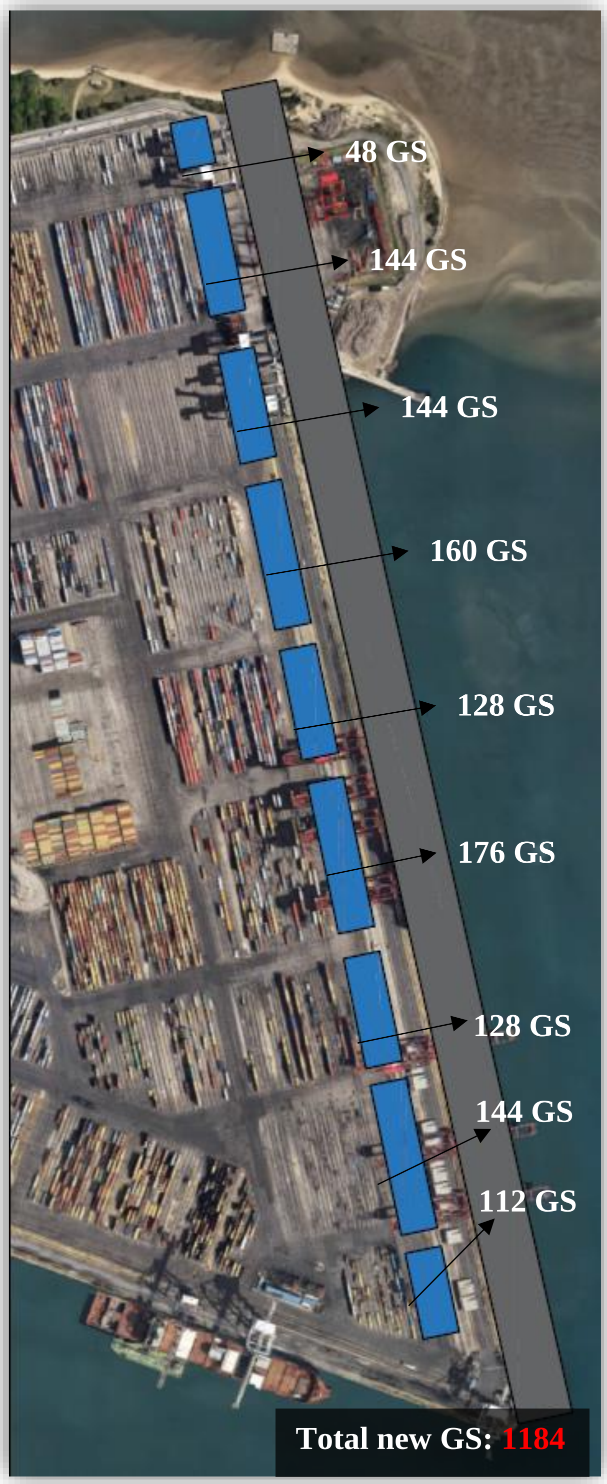

Figure 37 - New container stacks from extension of berth

Figure 37 shows the method that was used to calculate the number of additional ground slots that the expansion would create. The same calculation was done per the formula stated by Bestenbreur (2015) and can be seen in Table 19.

Table 19 - Container Yard Calculation for Pier 2, with expansion

Characteristic	***Unit***	***Pier 2***	***Pier 2 Expanded***
Transhipment	%	15	15
PF- Peak factor	-	1.1	1.1
TEU Factor	-	1.6	1.6
Dwell time	days	5	5
Available no. groundslots	-	16274	17458
Max. effective stacking height	Containers	3	3
Average stacking height	Containers	2.5	2.5
n1 = Average stacking height/Max. Effective stacking height	-	0.83	0.83
n3 = Ground slots Utilized/Ground slots available	-	0.95	0.95
n2 = Peak average stacking height/average stacking height		1.0	1.0
Q(di) + Q(lo)	Cont. moves/year	1 711 991	1 836 545
Quayside throughput generated by Container Stacking Yard	**TEU moves/year**	**2 739 185**	**2 938 472**

The above calculation shows that this expansion would have a large impact on the container yard stack capacity. The total amount of TEU throughput increased from around 2 740 000 TEU moves/year to 2 938 000 TEU moves/year. This increase was represented graphically and can be seen in Figure 38

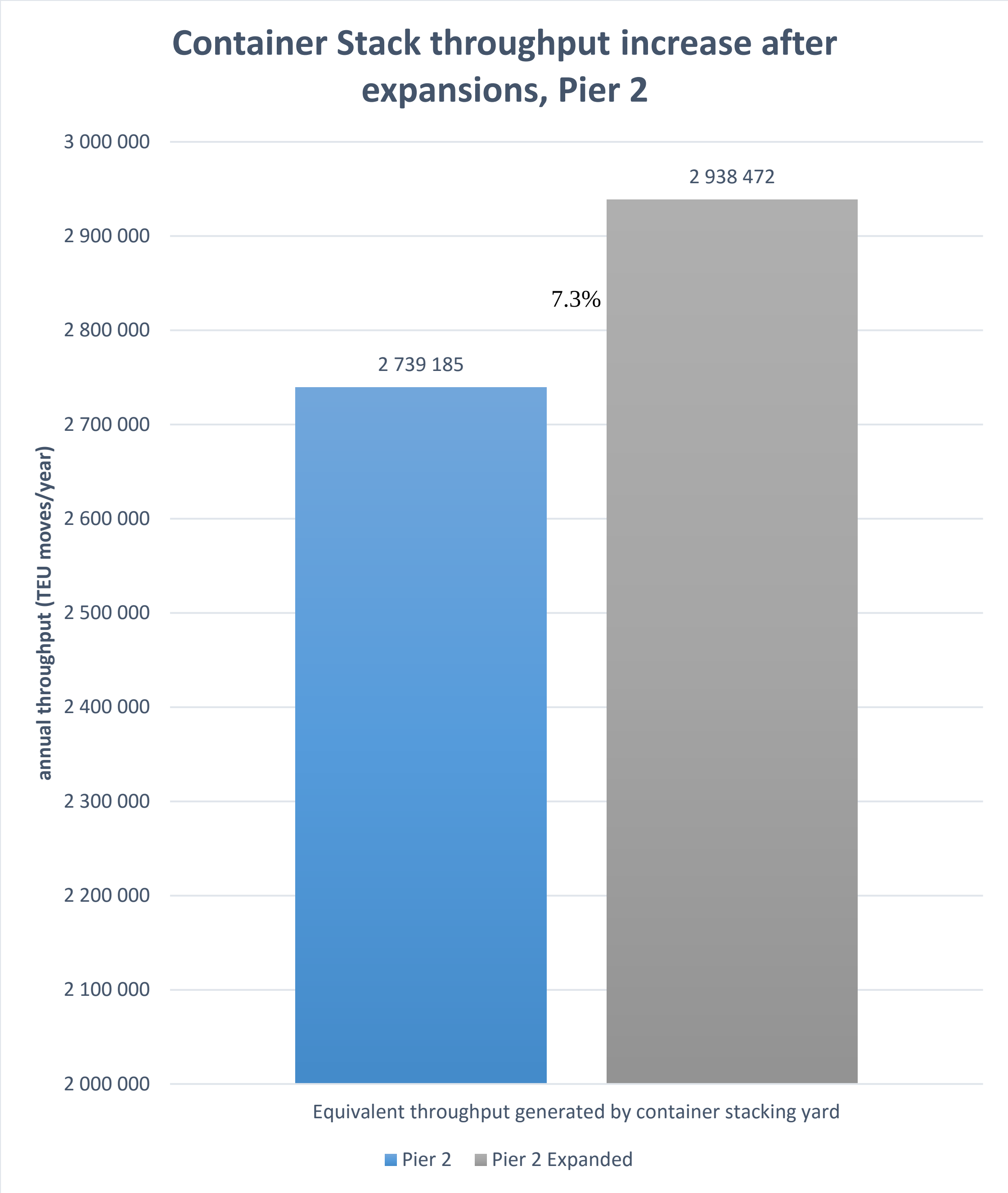

Figure 38 - Container Yard Capacity increase due to expansion

As seen in Figure 38 the expansions on Pier 2 would increase the container yard capacity by 200 000 TEU moves/year from around 2 595 000 to 2 784 000 TEU moves/year. (7.3% increase) The current container yard stack capacity is still the limiting container throughput constraint. To increase the container throughput for Pier 2, the container stack throughput would have to be increased to match the large throughput that the berths can achieve.

4.2.3 Analysis of Results

This section aims to compare the two crucial capacity constraints that were calculated in the preceding subsections. The data represents the capacity constraints for the DCT once the proposed expansions have taken place. The Bestenbreur method is used to represent the berth capacity, and is compared to the container stacking yard capacity. This will provide a conclusion as to which constraint would be limiting the capacity of the DCT.

Figure 39 shows the critical capacity constraints for the DCT:

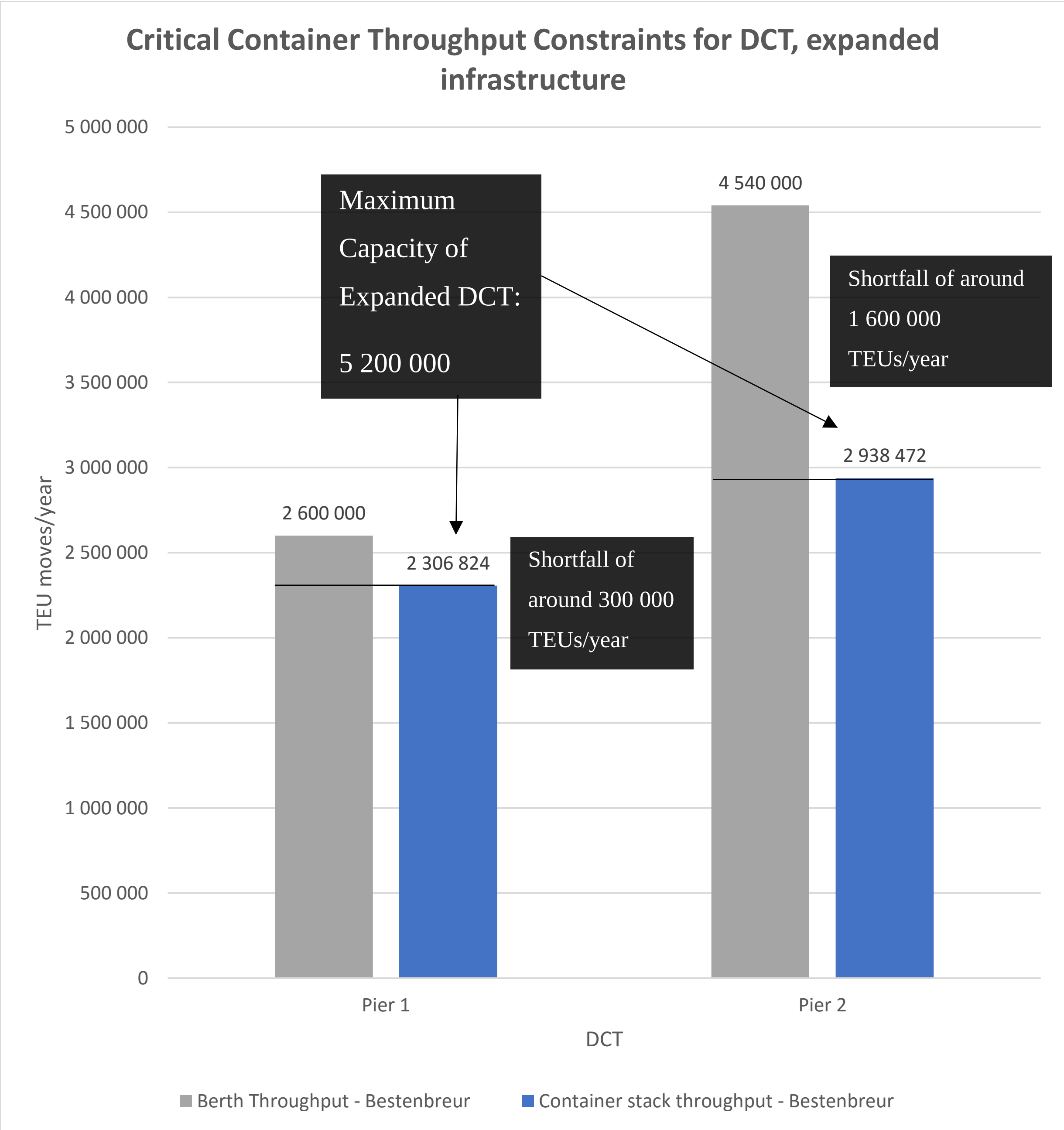

Figure 39 – Critical container throughput constraints for DCT

From Figure 39 the following conclusions were made:

- The container throughput **limiting constraint** for **Pier 1** was found to be the **container stacking yard capacity**, which would limit the terminal to around 2 300 000 TEU/year.
- The container throughput **limiting constraint** for **Pier 2** was found to be the **container stacking yard capacity**, which would limit the terminal to around 2 900 000 TEU/year.
- The **maximum capacity of the DCT** after expansions was calculated to be around **5 200 000 TEU moves/year**.
- The expansions would greatly increase the throughput for Pier 1, which is important for the development of the Durban Container Terminal.
- There was a **shortfall of 1 900 000 TEU moves/year** between the **berth capacity** and the **container stacking yard capacity**. For the DCT to operate at the optimal level, the container stacking yard capacity would have to be increased.

The above data is summarised in Table 20:

Table 20 - Capacity constraints of DCT - expanded infrastructure

	Pier 1	***Pier 2***	***Combined (DCT)***
Berth Capacity (TEU moves/year)	2 600 000	4 500 000	7 100 000
Container Stack Throughput (TEU moves/year)	2 300 000	2 900 000	5 200 000
Shortfall (TEU moves/year)	300 000	1 600 000	1 900 000

The increase in capacity should be analysed against the container throughput predictions that were calculated in Section 3.3, to determine if the DCT would be able to meet future container throughput levels. The analysis is shown in Figure 40:

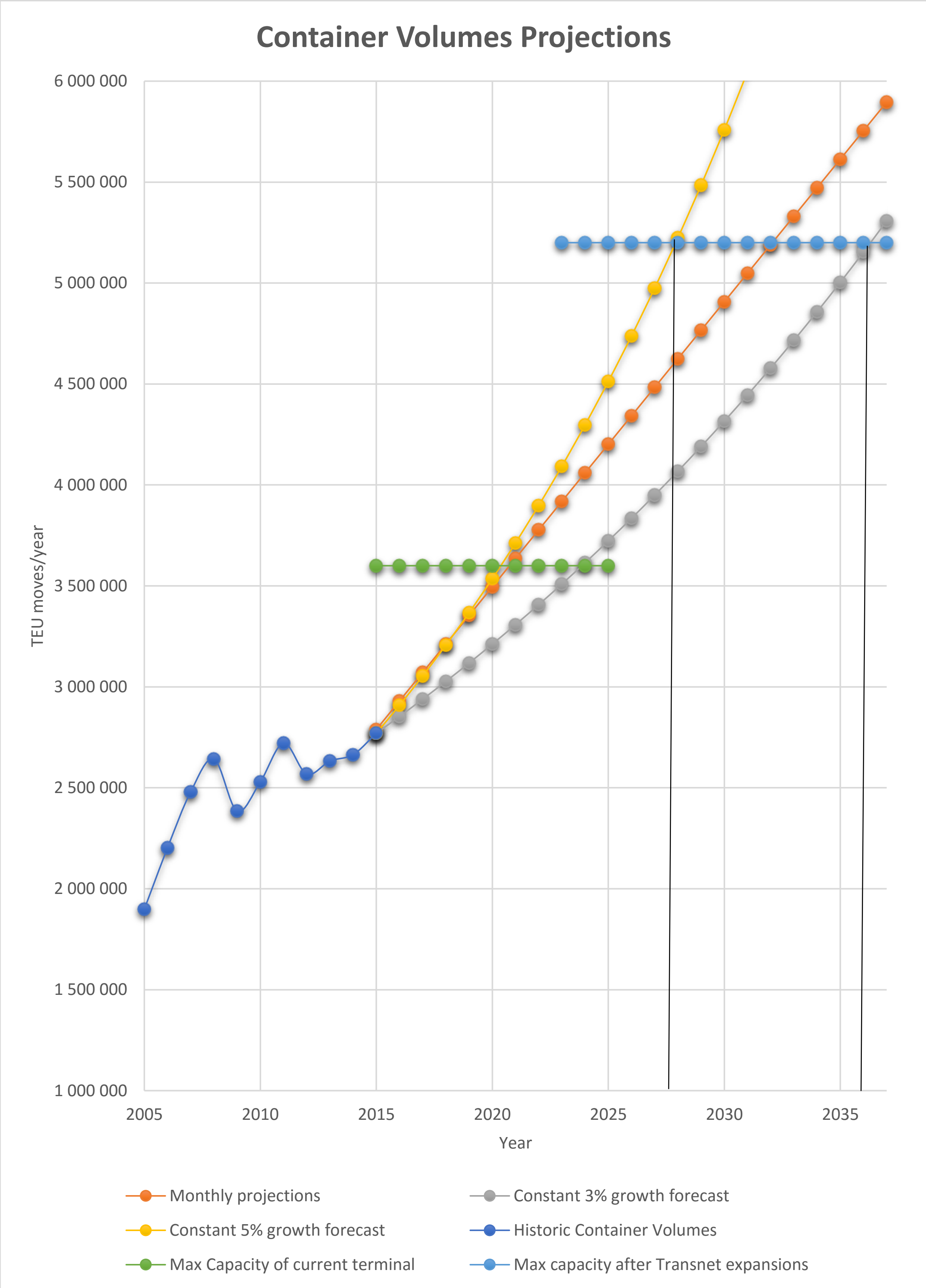

Figure 40 - Container Throughput predictions compared to DCT capacity

The following was concluded from the analysis of Figure 40:

- The DCT would **reach its maximum capacity**, after the Transnet Expansions have taken place, **between the year 2027 and 2036**. - Figure 40
- The above time period for the DCT reaching its maximum capacity is based on the three container growth models that are shown in Figure 40.

4.2.4 Conclusions

The effect that the proposed expansion would have on the DCT was analysed. Two critical container throughput limiting constraints were calculated for the current terminal, as well as the terminal once expansions had taken place.

The following conclusions were made for this section:

- The expansion plans were found to be a critical factor in the development of the Durban Container Terminal. The current infrastructure needs to be upgraded to deal with future demand.
- The expansions would increase the overall container throughput capacity **from 3.6 million TEU moves/year to around 5.2 million TEU moves/year**
- The overall container throughput is **limited by the container stacking yard**, for both Pier 1 and Pier 2. It is recommended that the throughput that the container stacking yard can handle be increased to match the large berth capacity.
- There was a **shortfall of 1 900 000 TEU moves/year** between the **berth capacity** and the equivalent **container stacking yard capacity**
- The rail/truck terminal capacities were analysed, and recommendations for upgrades were provided. Pier 1 would have to upgrade the rail terminal to handle the increased container throughput generated by the proposed expansions.

Chapter 5

Opportunities to increase capacity of Durban Container Terminal

The aim of this section is to provide solutions to further increase the capacity of the DCT. The capacity of the berths was calculated to be substantially more than the container stacking yard capacity. To increase the maximum capacity of the DCT solutions should be aimed at increase the capacity of the container stacking yard. This section will analyse the following solutions:

- Change of stacking system for Pier 2, from straddle carrier to RTG system – section 5.1
- "Masterplan" – Active dwell time monitoring and the implementation of the dry port concept – section 5.2.

5.1 Impact of change in stacking system, Pier 2

The DCT Pier 2, is currently operating with a straddle carrier system. The system provides good flexibility and workability, but in terms of TEU/ha, the RTG system is more efficient in achieving a higher container throughput in the container stacking yard. This section will analyse the effect of a change in stacking system from straddle carrier to the RTG "1 over 5"-shuttle carrier system. The comparison is drawn against the **expanded Pier 2**, as the proposed expansions will commence in 2017/2018. The same formula was used stated in Section 3.2.2.

calculation:

Table 21 shows the above-mentioned calculation:

Table 21 - Increase in throughput that container stacking yard can generate, due to change in stacking system

Characteristic	***Unit***	***Pier 2 Expanded***	***Pier 2 + Expanded RTG***
Transhipment	%	15	15
PF- Peak factor	-	1,1	1,1
TEU Factor	-	1,6	1,6
Dwell time	days	5	5

Available no. groundslots	-	17458	17458
Max. effective stacking height	Containers	3	5
Average stacking height	Containers	2,5	3,5
n1 = Average stacking height/Max. Effective stacking height	-	0,83	0,7
n3 = Ground slots Utilized/Ground slots available	-	0,95	0,9
Q(di) + Q(lo)	Cont. moves/year	1 836 545	2 445 621
Quayside throughput generated by Container Stacking Yard	**TEU moves/year**	**2 938 472**	**3 912 994**

It was observed that the **container stacking yard capacity increased** by around **980 000 TEU moves/year** from the current system to a RTG "1 over 5" system. The above calculation is represented visually in Figure 41.

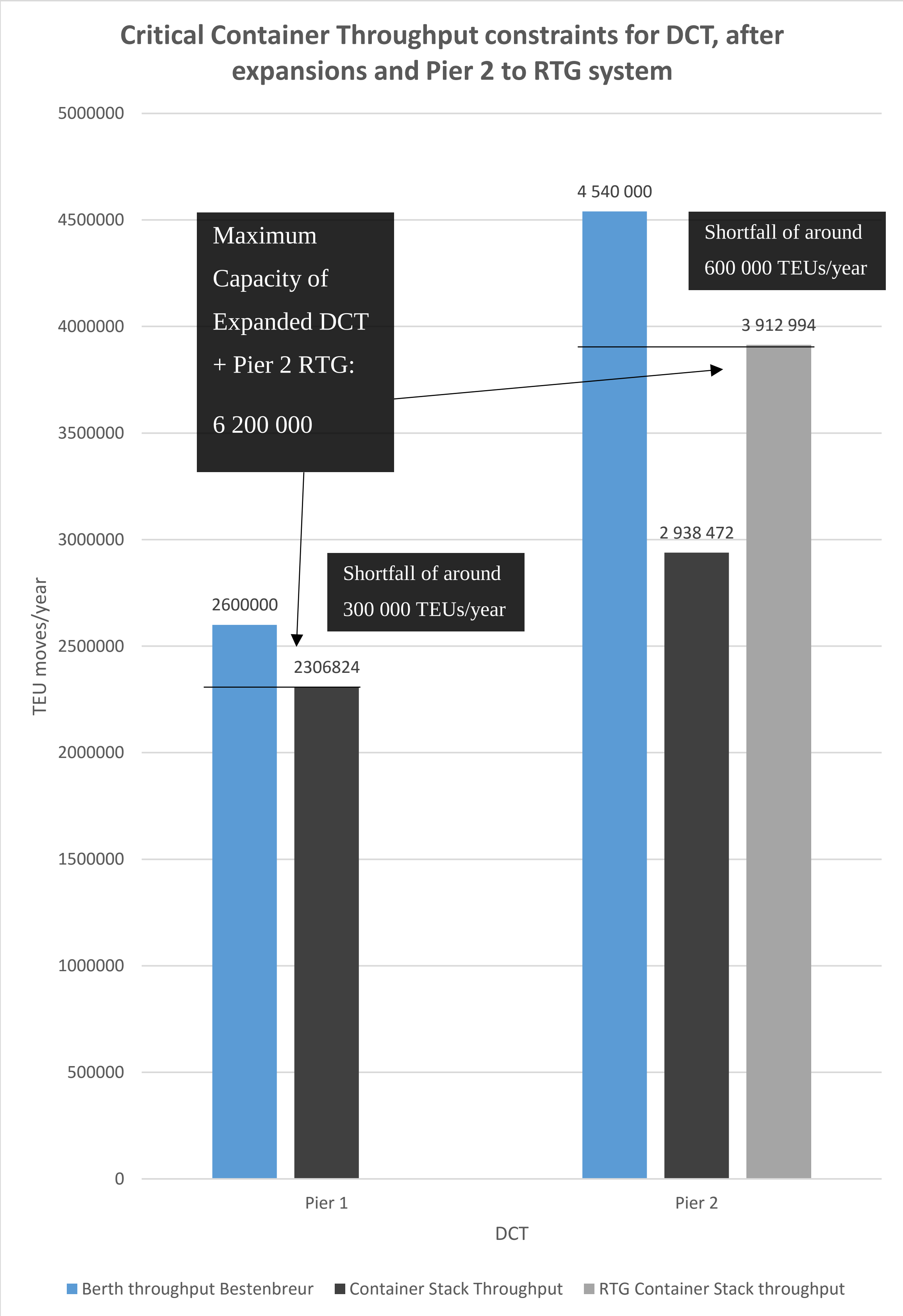

Figure 41 - Comparison of berth capacity vs container stacking yard capacity for an RTG system, Pier 2

From the analysis of Figure 41 the following was concluded:

- Changing the stacking system for Pier 2 from straddle carrier, to a RTG "1 over 5" system would **increase the throughput** generated by the container stacking yard by **around 980 000 TEU moves/year.**
- **The maximum capacity of the DCT** was calculated to be around **6 200 000 TEU moves/year,** once the change in stacking system has been implemented.
- There would still be **a shortfall** in throughput between the berth and container yard stack throughput for DCT – around **900 000 TEU moves/year.**
- For the terminal to reach its maximum yearly throughput, the container stack yard must be adjusted to handle more containers. Due to lack of space for further expansion it is recommended that the dwell time be reduced. This is usually achieved via the implementation of a dry port. The subsequent section will analyse this option.

The above data is summarised in Table 22:

Table 22 - Capacity constraints of DCT - after Pier change to RTG system

	Pier 1	***Pier 2 RTG***	***Combined (DCT)***
Berth Capacity (TEU moves/year)	2 600 000	4 500 000	7 100 000
Container Stacking yard Capacity (TEU moves/year)	2 300 000	3 900 000	6 200 000
Shortfall (TEU moves/year)	300 000	600 000	900 000

The shortfall between the berth capacity and the equivalent container stacking yard capacity is now significantly less. The DCT will be operating at the maximum capacity if the equivalent container stacking yard capacity matches the berth capacity (7.1 million TEU moves/year). The reduction of container dwell time increases the equivalent container stacking yard capacity and will thus be investigated to acquire the optimal dwell time for the DCT.

5.2 Masterplan

This section describes the "Masterplan", which is a solution to increase the maximum capacity of the DCT to the most optimal level. This level is defined in this report as the point where the container stacking yard capacity equals the berth capacity. This is due to the DCT berths reaching the maximum size given the available space for container related activities.

Section 5.1 shows the calculation of the DCT capacity after the change in stacking system, from Straddle Carrier to the RTG system, for Pier 2. After the implementation of this system there remained a shortfall between the container stacking yard capacity and the berth capacity, of around 900 000 TEU moves/year.

5.2.1 Impact of reduction in container dwell time

The container dwell time has a direct impact on the equivalent container stacking yard capacity. This section will aim to calculate the optimal dwell time for the DCT, which is defined as the point at which the berth capacity equals the equivalent container stacking yard capacity. Figure 42 shows the method to obtain the optimal dwell time – which, if maintained, would enable the DCT to operate at its maximum capacity of 7.1 million TEU moves/year.

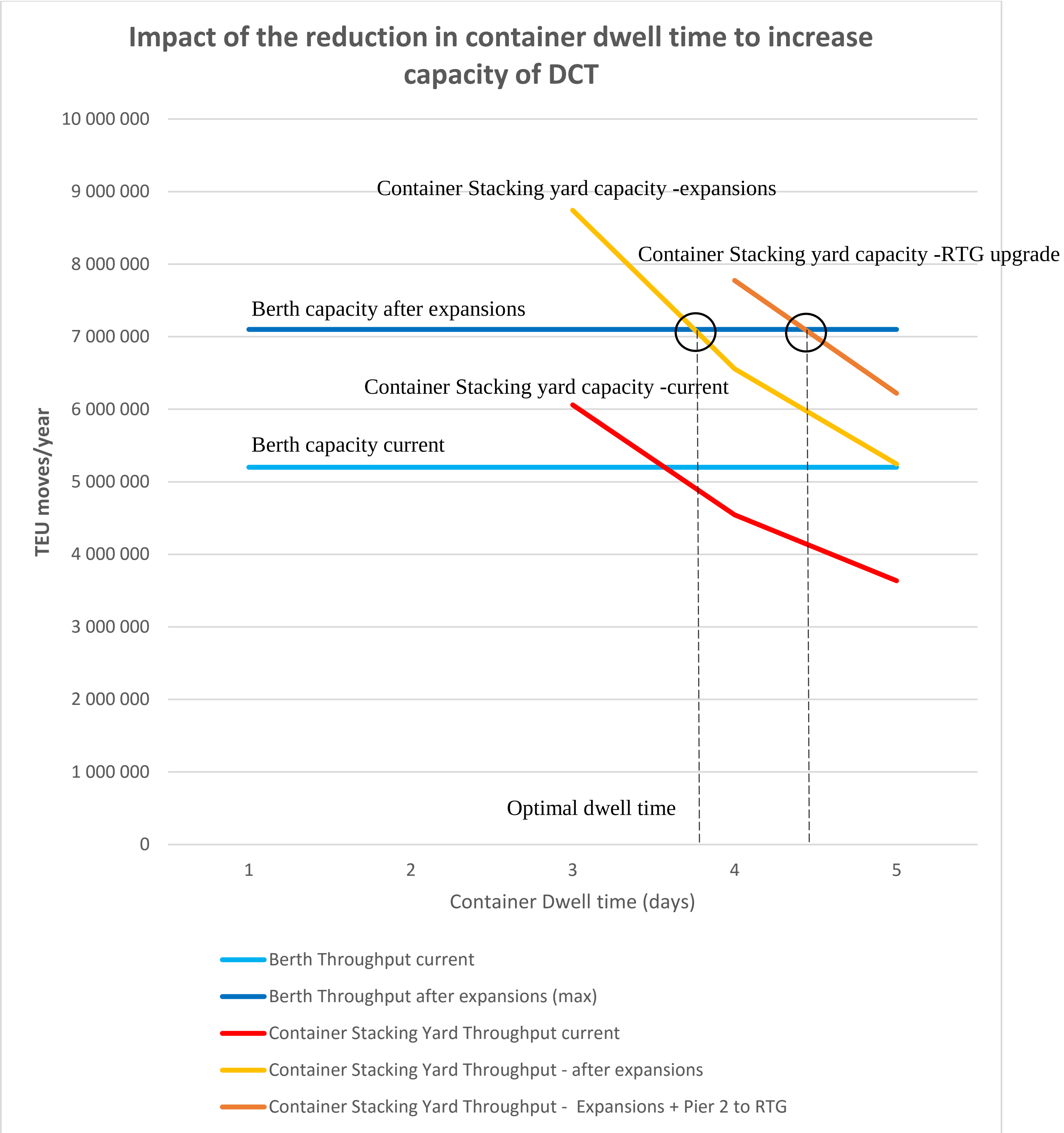

Figure 42 – Impact of a reduction in container dwell time for the DCT

The following conclusions were made from the analysis of Figure 42:

- The expansions outlined in Section 4.1 are set to start in 2017, and thus the optimal dwell time was calculated for the expanded DCT.
- **The optimal dwell time is defined** as the point at which the **berth capacity equals** the equivalent **container stacking yard capacity**.
- The **optimal dwell time**, **after expansions** have been complete is around **3.75 days**.

- The **optimal dwell time**, **after expansions** have been complete, and **Pier 2 has been changed to a RTG system**, is around **4.3 days**.

The above conclusions show that the DCT would have to reduce the container dwell time to increase the maximum capacity of the terminal. Mr. T. Bestenbreur recommended that the use of a dry port be investigated for the DCT. Thus, the "Masterplan" includes the use of a dry port, active dwell time management of 4 days, as well as the change in stacking system shown in Section 5.1.

5.2.2 Use of a dry port

The "Masterplan" includes the use of a dry port, along with active dwell time management, to maximise the capacity of the DCT. It is recommended that the dwell time be managed in the following way:

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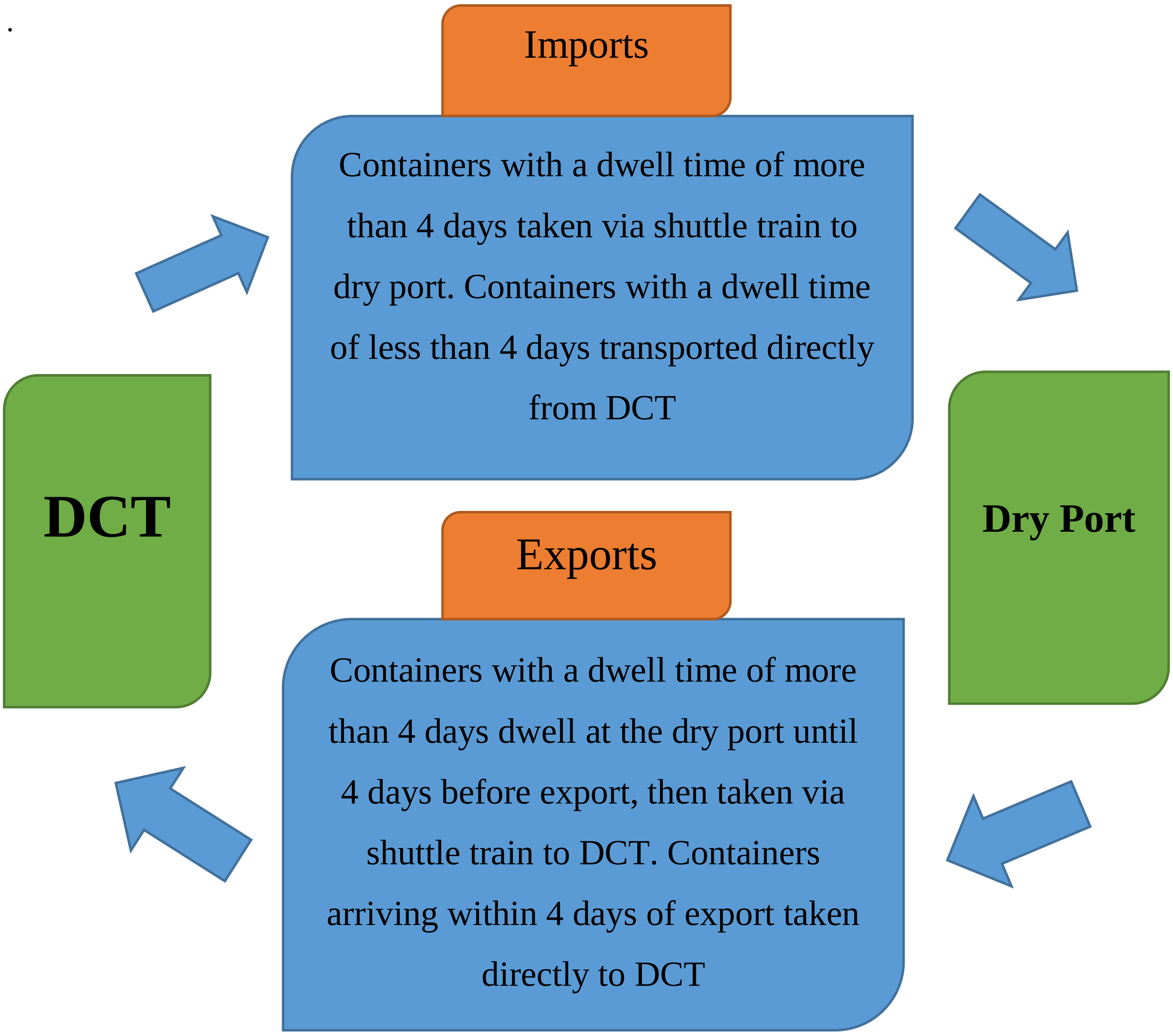


Figure 43 - Dwell time management for DCT

The effect that this proposed option would have on the critical container capacity constraints can be seen in Figure 44. Note that the dwell time has been reduced and controlled at 4 days. This would enable the DCT to operate at an optimal level.

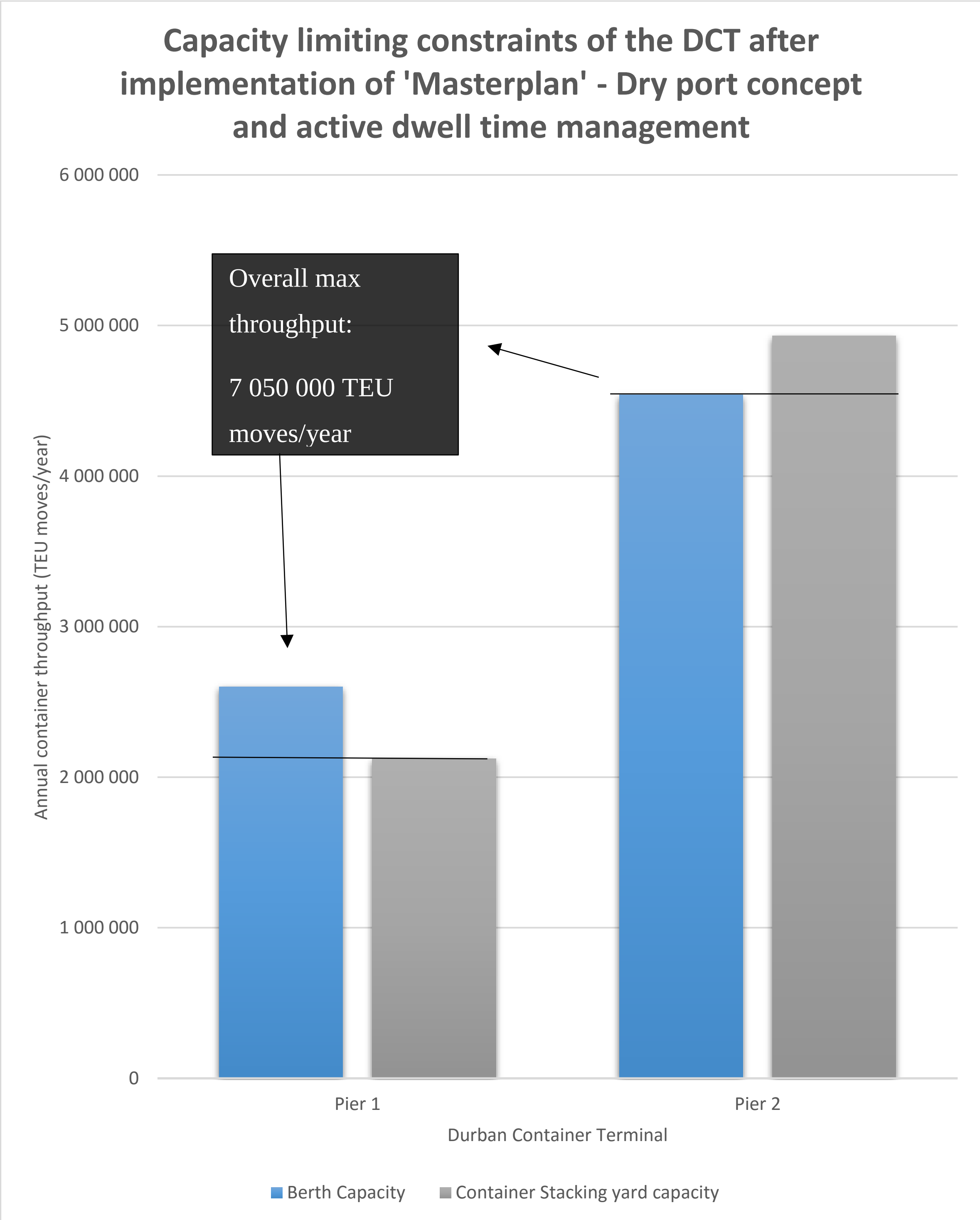


Figure 44 – Capacity limiting constraints for expanded DCT + Pier 2 to RTG + reduction in dwell time to 4 days

Location of dry port

Two locations have been identified for the implementation of a dry port:

Bayhead Road site

This site is located close to the DCT, and the area has been included in the expansion plans set out by Transnet (2014), outlined in Section 4.1. An additional 308 Ha is available for back of port logistics. Figure 45 shows the location of the Bayhead Road site.

Figure 45 - Location of Bayhead Road site, adapted from Google Earth (2016)

Conceptual Design of Bayhead Road dry port

The aim of this chapter is to present the design of the Bayhead Road dry port. The dry port contains: an export container stack; an import container stack; two rail terminals (a hinterland terminal and a shuttle train terminal to DCT); and a truck loading terminal. The calculations for the rail terminals, truck loading terminal and number of required ground slots have been included in Appendix C. The overall layout of the Bayhead Road "transfer centre" is shown in Figure 46:

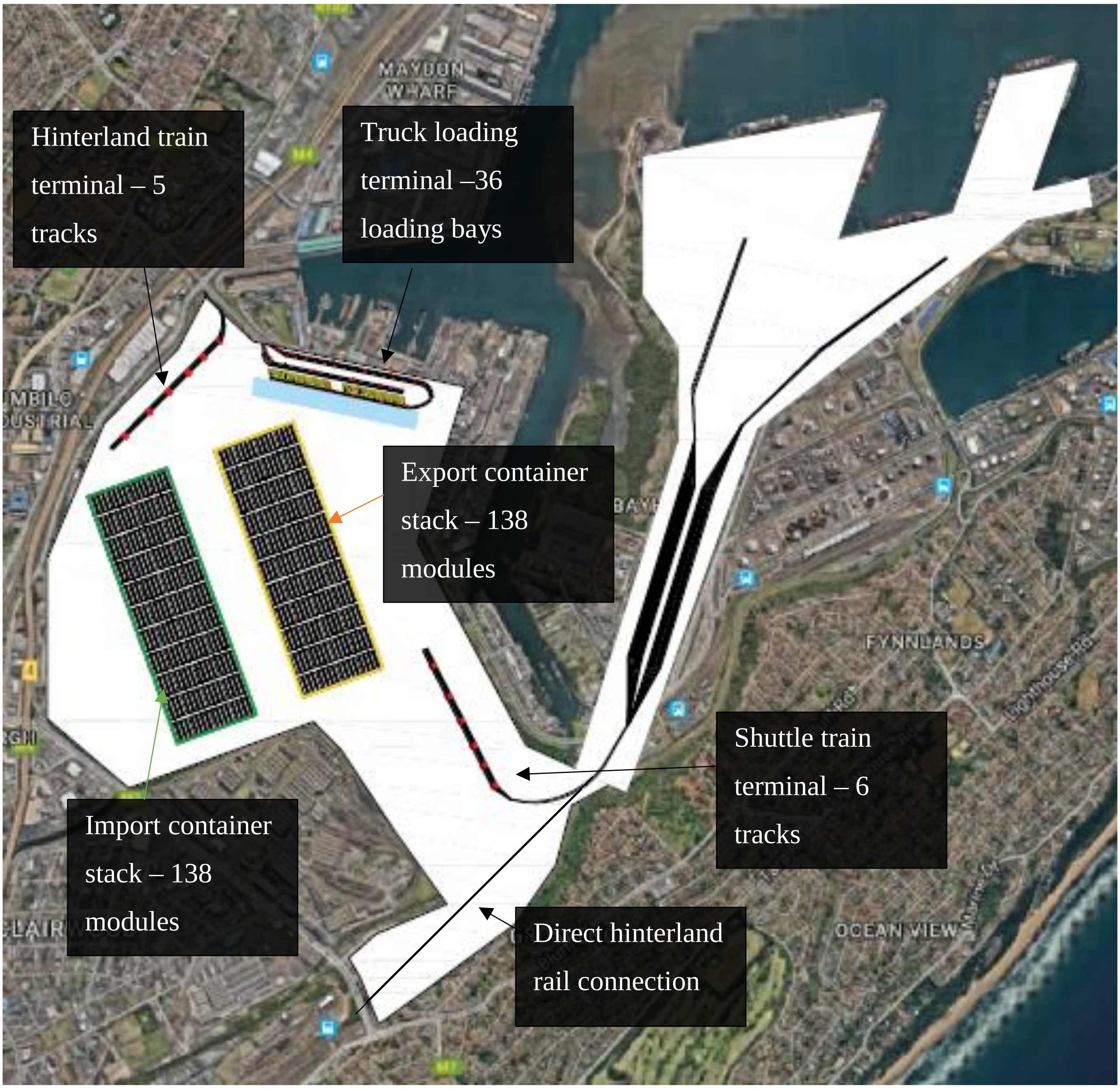


Figure 46 - Layout of Bayhead Road dry port

Old Durban Airport site

The second option involves the use of the old Durban Airport site as a dry port. The site is located around 11km from the DCT. The site has been made available for the container related activities, as the Durban Dig-out Port has been put on hold. Figure 47 shows the location of the proposed dry port:

Figure 47 - Location of proposed dry port, adapted from Google Earth (2016)

Conceptual Design of Dry Port

The aim of this chapter is to present the conceptual design of the dry port on the old Durban Airport site. The dry port contains: two rail terminals (a hinterland terminal and a shuttle train terminal to DCT); and a truck loading terminal. The calculations for the rail terminals, truck loading terminal and number of required ground slots have been included in Appendix D. The overall layout of the dry port is shown in Figure 48:

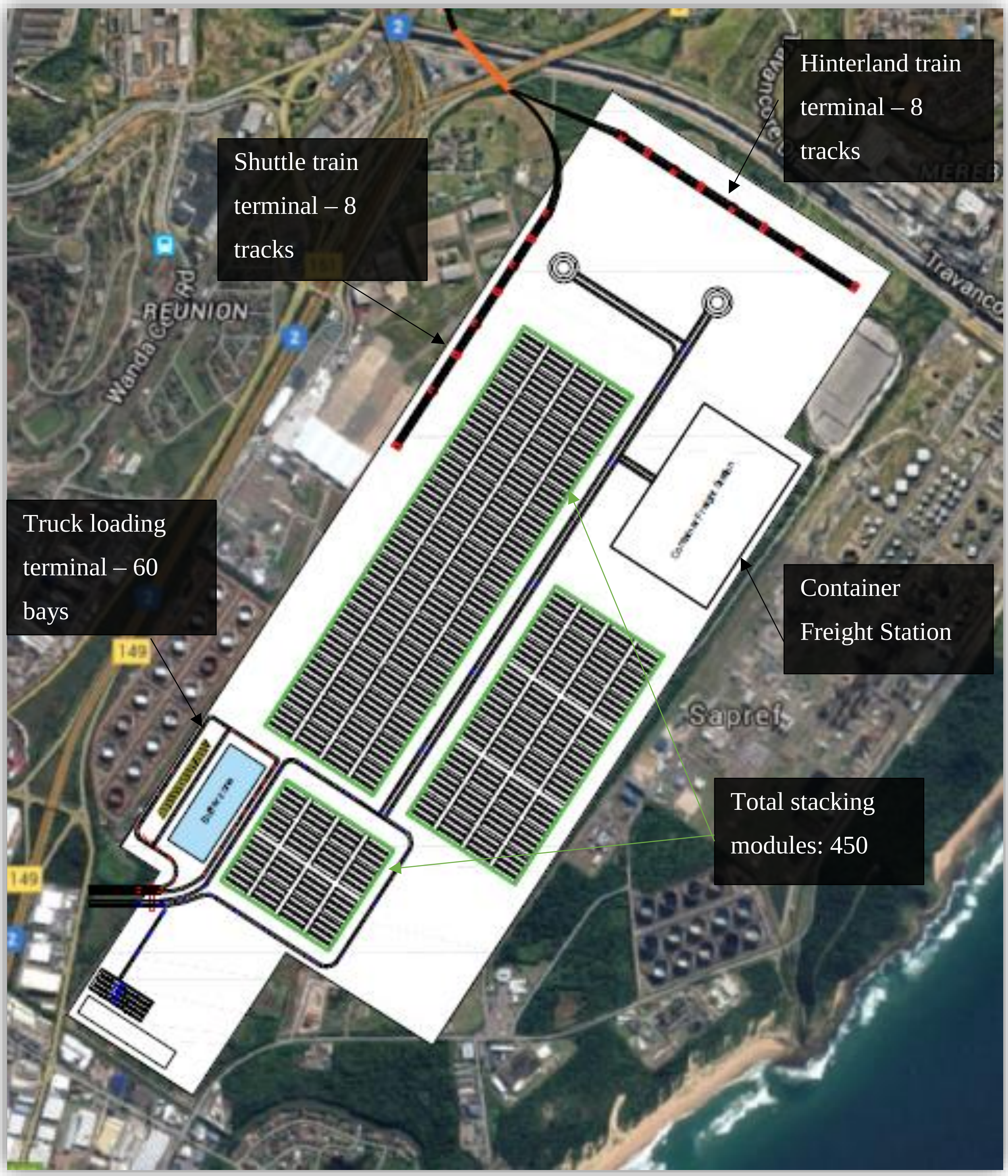


Figure 48 - Layout of the proposed dry port, on the old Durban Airport site

5.2.3 Conclusion

The capacity of the DCT after the implementation of the "Masterplan" is compared to the container throughput projections (Section 3.3) is shown in Figure 49.

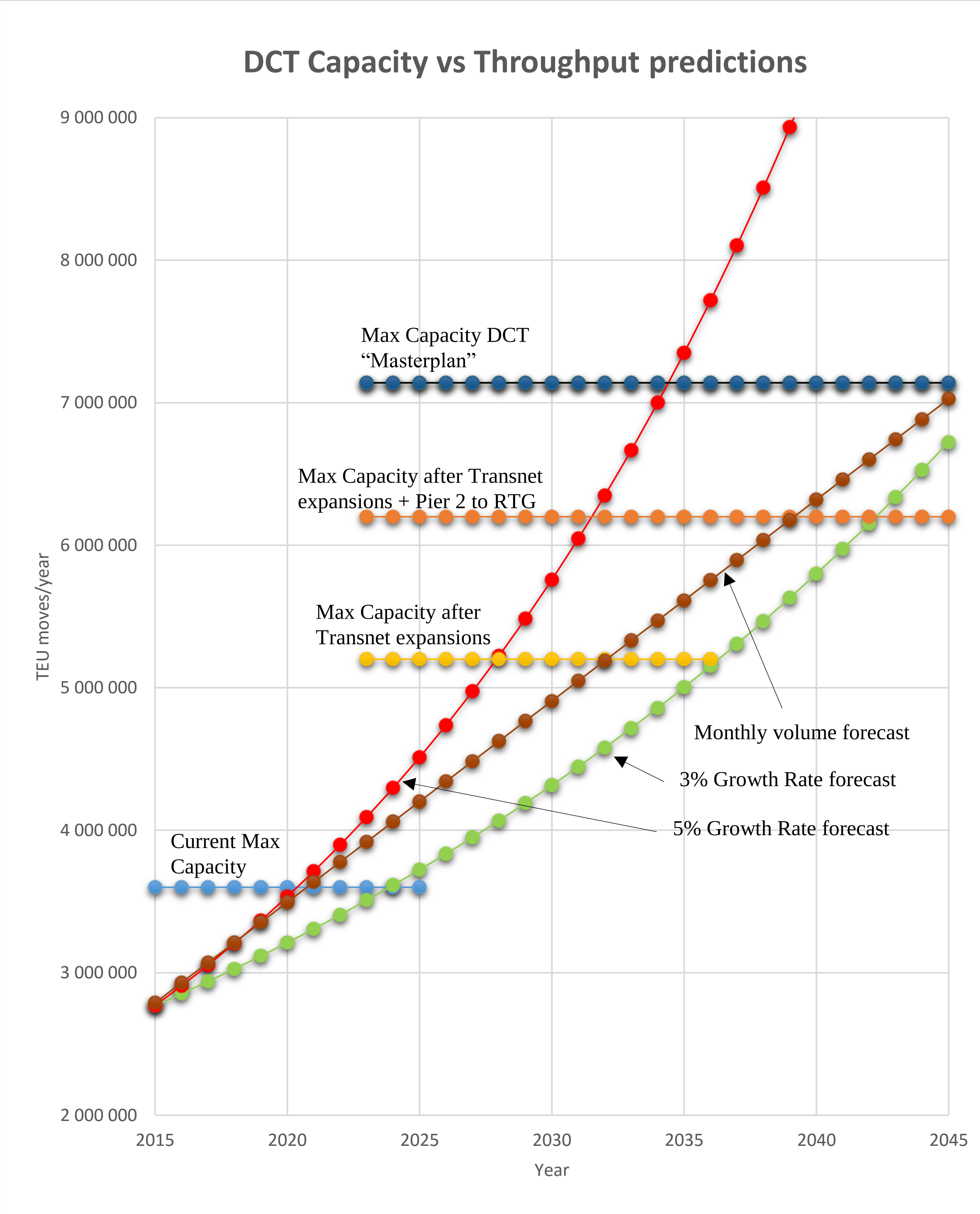


Figure 49 - DCT Capacities vs forecasted container throughput volumes

The following was concluded from analysis of Figure 49:

- The **maximum capacity** of the DCT **after Transnet expansions** was calculated as **5 200 000** TEU moves/year. Forecasted container throughput volumes indicate that the terminal would then **reach** its maximum capacity **between 2027 and 2036**.
- The **maximum capacity** of the DCT **after Transnet expansions and Pier 2** changed to **RTG system**, was calculated as **6 200 000** TEU moves/year. Forecasted container throughput volumes indicate that the terminal would then **reach** its maximum capacity **between 2032 and 2042**.
- The **maximum capacity** of the DCT after the implementation of **the "Masterplan"** was calculated as **7 050 000** TEU moves/year. Forecasted container throughput volumes indicate that the terminal would then **reach** its maximum capacity **between 2035 and 2045**.

The following was concluded about the feasibility of the solutions proposed in Chapter 5:

- The change in stacking system for Pier 2 is considered vital to the development of the DCT. The change directly increases the maximum capacity by around 1 million TEU moves/year.
- The "Masterplan" includes the change in stacking strategy for Pier 2, active dwell time monitoring and control (4 days), and the construction of a dry port. Two locations were investigated for the construction of a dry port:
    - Option 1: Bayhead Road site
        - This option increases the maximum capacity of the DCT to 7.14 million TEU moves/year.
        - The site is located very close to the DCT.
        - The site has connection to the hinterland markets via rail and road corridors.
        - This option would reduce congestion in the DCT.
        - The site has additional space for container stacks or logistical activities.
    - Option 2: Old Durban Airport
        - The dry port site is located around 11km to the DCT.
        - The initial capital cost of this option is very high.
        - The site has ample space for stacking.
        - Additional construction on a bridge for the rail network to reach the dry port would be expensive.

- The Bayhead Road site was deduced to be more feasible for the location of a dry port, due to the following:
    - The Bayhead Road site is significantly closer to the DCT than the old Durban Airport site. The cost of shuttling containers would be significantly cheaper to the Bayhead Road site. The operating costs would be less for the Bayhead Road option.
    - The Bayhead Road option would cost considerably less to construct and implement than the dry port option.
    - The Bayhead Road site has more efficient connections to the hinterland market, due to infrastructure that serves the DCT.

The “Masterplan” is proposed to increase the capacity of the DCT from 5,2 million TEU moves/year to around 7.05 million TEU moves/year.

Chapter 6

Conclusions and recommendations

This chapter presents the most significant conclusions drawn from the results of this study. It starts with conclusions on the container trade in South Africa. The chapter then presents the conclusions of the capacity limiting constraints of the DCT, currently and after proposed expansions have been complete. The chapter ends with conclusions about the solutions proposed to further increase the capacity of the DCT, with emphasis on the feasibility of the dry port concept.

6.1 Containerised trade of South Africa

The annual container throughput volumes for South Africa were analysed. The growth of the container trade varied over the last 10 years. The percentage of growth in annual container volumes was dependant on the state of the national and global economy. The following was concluded about container throughput levels in South Africa:

- The container throughput decreased between 2008-2009 by 9.75%. This was due to the recession that was experienced in South Africa, and across the globe. Once the recession passed the container volumes grew by around 5% between the years 2010-2015.
- The overall average of growth for South African container trade was 4.6% per year between 2005-2015. This indicated that in the medium and long term the country experienced growth in container trade.
- The South African ports would thus need to keep expanding to meet the present demand. It is recommended that the growth be monitored in the next few years, which would give a better indication of the future of container trade in South Africa.

6.2 Capacity limiting constraints for the DCT – current infrastructure

In a logistic chain, the chain is a strong as its weakest link. For the DCT this is represented by the capacity limiting constraint. The two critical container throughput constraints - the berth capacity, and the container yard stack capacity were compared to determine which was limiting the maximum capacity of the DCT. The rail/road terminals capacities, and container crane capacities were also calculated, but these constraints are variable and easily upgraded and were thus not compared to the two critical capacity limiting constraints. Table 23 shows the conclusion of the capacity limiting constraints.

Table 23 - Capacity limiting constraints summary for the DCT

	Pier 1	***Pier 2***
Berth Capacity	1 200 000 TEU moves/year	4 000 000 TEU moves/year
Equivalent Container stacking yard capacity	890 000 TEU moves/year Limiting	2 700 000 TEU moves/year Limiting
Shortfall	300 000 TEU moves/year	1 300 000 TEU moves/year
Combined Shortfall	1 600 000 TEU moves/year	

The following was concluded about the current DCT capacity:

- The DCT maximum capacity is **limited** by the **equivalent container yard stack throughput**.
- This study calculated the maximum capacity of the current DCT to be **3 600 000 TEU moves/year**
- Per the best estimate, the terminal would reach its **maximum capacity** between the **year 2020 and 2024** (Figure 50)
- There was a shortfall between the berthing throughput and the equivalent container stacking yard capacity of around 1 600 00 TEU moves/year.

6.3 Capacity limiting constraints after Transnet Expansions

This section aims to deduce a conclusion on the capacity limiting constraints for the DCT after two Transnet Expansions (see Section 4.2) have been completed. The expansions mentioned are starting in 2017, thus this section will determine which constraint will hinder the growth of container volumes for the future, for the DCT.

The same constraints were analysed as in Section 3, and are summarised in Table 24 below:

Table 24 - Summary of capacity limiting constraints for expanded terminals

	Pier 1	***Pier 2***
Berth Capacity	2 600 000 TEU moves/year	4 540 000 TEU moves/year
Equivalent Container stacking yard capacity	2 300 000 TEU moves/year Limiting	2 940 000 TEU moves/year Limiting
Shortfall	300 000 TEU moves/year	1 600 000 TEU moves/year
Combined Shortfall	1 900 000 TEU moves/year	

The following conclusions and recommendations were made:

- The DCT maximum capacity is still being **limited** by **the container yard stack throughput**
- This study calculated the **maximum capacity** of the DCT, after Transnet Expansions have taken place, to be around **5 200 000 TEU moves/year.**
- The DCT would reach its **maximum capacity**, after Transnet Expansions have taken place, between the **year 2027 to 2036**, according to container growth models shown in Figure 50.
- There was a shortfall between the berth capacity and the equivalent container stacking yard capacity of around 1 900 000 TEU moves/year.
- The terminal would have to increase the container stacking yard capacity to increase the maximum capacity of the DCT.
- The rail/truck terminals should be upgraded – see Appendix B.3 for recommendations.

Figure 50 shows the annual container throughput capacity compared to the container throughput growth for the future and is relevant for Section 8.4-8.8:

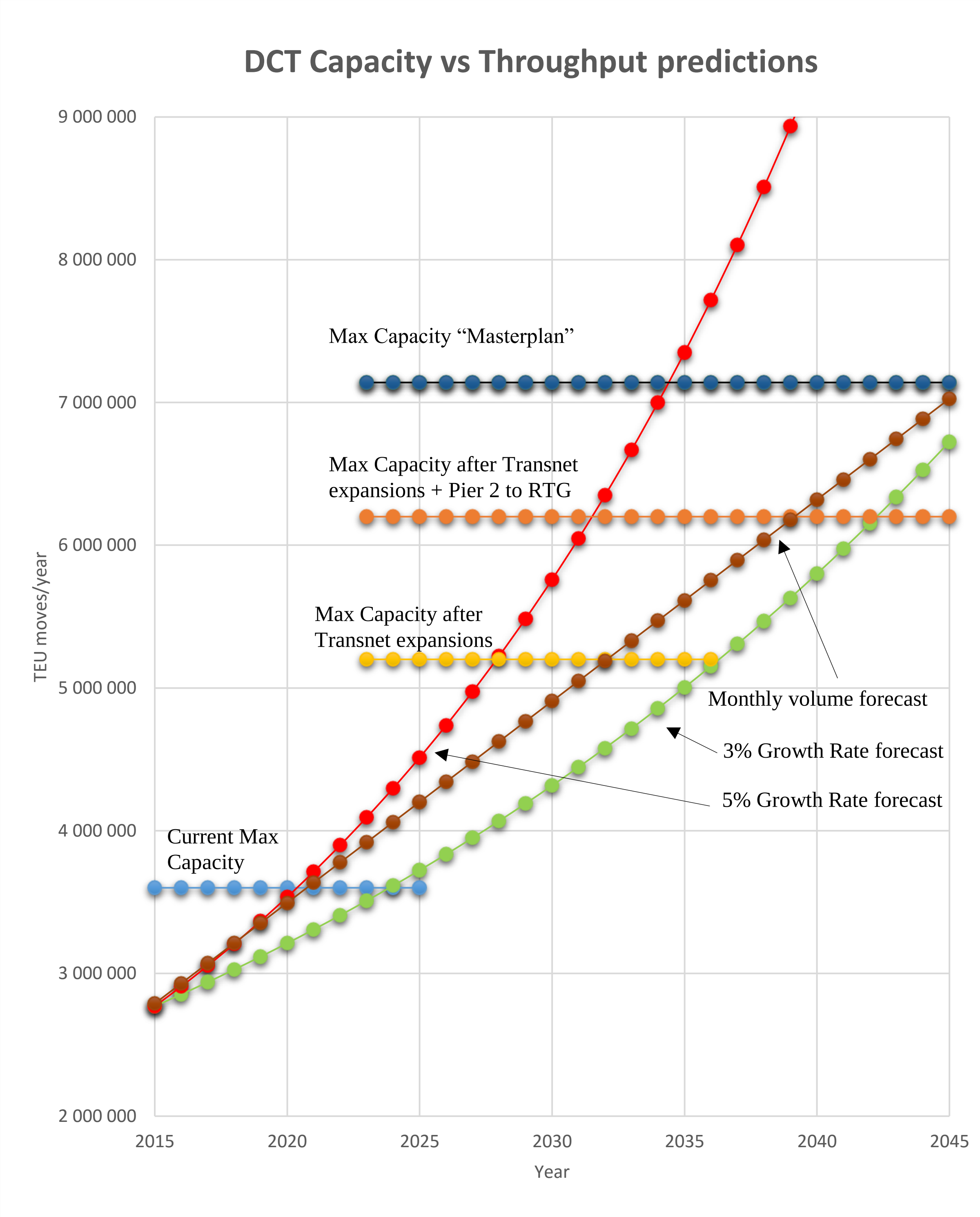


Figure 50 - DCT Capacities vs forecasted container throughput volumes

6.4 Solutions to increase capacity

6.4.1 Change in stacking system – Pier 2

Section 5.1 analysed the effect of changing the stacking system for Pier 2. The straddle carrier system is currently being used for Pier 2. The RTG system was found to achieve a larger throughput per hectare, and was thus investigated. The following was concluded:

- An RTG system for Pier 2 would **increase the overall container throughput** by around **980 000 TEU moves/year**.
- The overall capacity of the DCT would be **6.2 million TEU moves/year** after the change in stacking system.
- The DCT would reach its maximum capacity, after the proposed upgrade of Pier 2, between the year 2032 and 2042 (Figure 50)
- The **equivalent container stacking yard capacity** was still **limiting** the overall throughput, due to the large throughput that the berths can handle.
- This study recommends this change in stacking system to increase the capacity of the DCT.

6.4.2 Masterplan

The "Masterplan" is the name given to the solution to further increase the capacity of the DCT. The plan involves the following aspects:

- Implementation of the above-mentioned change in stacking system for Pier 2
- Active dwell time monitoring and control to a dwell time of 4 days.
- Implementation of the dry port concept.

Two locations were identified for the dry port site: the Bayhead Road site, which is located very close to the DCT and would allow for cost effective transportation of containers; the old Durban Airport site, which would require a much larger capital input than the Bayhead Road site. The Bayhead Road site can also make use of all the rail and road connections that serve the DCT, whereas the old Durban Airport site would require excessive construction to connect with the rail networks. The Bayhead Road site was deduced to be the most feasible location for a dry port. The dry port concept is deduced as a feasible and plausible alternative for the DCT to increase its maximum annual container throughput capacity

The following was concluded about the "Masterplan":

- The "Masterplan" would increase the annual container throughput capacity of the DCT to around 7.05 million TEU moves/year.
- The plan is reliant on strict dwell time management and control
- The "Masterplan" would enable the DCT to handle container throughput volumes until between 2034 and 2045, depending on the growth of the containerised industry.

6.5 Recommendations

The following recommendations are made:

- The dry port concept is a feasible option for the DCT to increase the maximum container throughput capacity. The "Masterplan" solution is recommended to maximise the capacity of the DCT.
- The container throughput volumes of South Africa, and specifically the DCT, should be monitored over the next 5 years.
- Logistical modelling should be performed for the implementation of a dry port.

6.6 Project Objectives

The main objectives for this thesis are restated:

I. To conduct a literature review of research which is relevant to this project:

II. To analyse the container throughput history for the DCT and analyse predictions/projections for future container volumes.

III. To determine which constraint(s) were limiting the current capacity of the container terminal. Two main capacities were analysed which could have been limiting the container throughput, namely the berth capacity and the equivalent container stacking yard capacity.

IV. To determine the effect that proposed expansions have on the capacity limiting constraints stated in Objective III.

V. To develop solutions for the DCT to increase the maximum container handling capacity, which include a change in stacking strategy for Pier 2, as well as a masterplan which includes active dwell time management and the use of a dry port to serve the DCT.

All five objectives were accomplished in this study. The DCT was analysed and the feasibility of the dry port concept was investigated. The dry port concept was deduced to be a feasible solution for the DCT to increase the maximum container throughput capacity.

References

Alderton, P (2008). Port Management and Operations. 3rd ed. : Informa Publisher. Chapter 7.

Bestenbreur, T. (2015), *Capacity Constraints and Key Performance Indicators.* University of Stellenbosch.

Bestenbreur, T. (2016), Meeting held on 30th August 2016, at University of Stellenbosch

Buthelezi, B. (2016). TEU data for the Port of Durban. Bogumusa.Buthelezi@transnet.net

Chamber marketing and communication. (2013). *Developments of the Port of Durban.* Available: http://durbanchamber.co.za/profiles/blogs/developments-on-the-port-of-durban [Last accessed 19th Feb 2016]

Committee on Productivity of Marine Terminals. (1986). Chapter 4. In, Improving productivity in U.S Marine Container Terminals. United States: DOI. 25

Creamer, T. (2016). TNPA to add container capacity at Durban harbour as it puts dig-out port on hold. Available: http://www.engineeringnews.co.za/article/tnpa-to-add-container-capacity-at-durban-harbour-as-it-puts-dig-out-port-on-hold-2016-06-28 . [Last accessed 19th July 2016].

Cullinane, K.P.B. and Wilmsmeier, G. (2011) The contribution of the dry port concept to the extension of port life cycles. In: J.W. Böse (ed.) Handbook of Terminal Planning, Operations Research Computer Science Interfaces Series, Vol. 49. Heidelberg, Germany: Springer, pp. 359–380.

Google Maps (2016), Map of Durban Container Terminal [online]. Google. Available from: https://www.google.co.za/maps/@-29.8866684,31.014391,14z?hl=en Last Accessed [25th October 2016]

Gooley, T.B. "The Geography of Logistics." Logistics Management and Distribution Report January 1998, 63-65.

Liebherr. (2016). *Technical description rubber tyre gantry crane.*Available: https://www.liebherr.com/shared/media/maritime-cranes/downloads-and-brochures/brochures/lcc/liebherr-rtg-cranes-technical-description.pdf [Last accessed 8th September 2016]

Ligteringen, H. and Velsink, H (2012). Ports and Terminals. 2nd ed. Netherlands: -. Chap. 7 p2-24.

Leitner, SJ and Harrison, R. (2001). The Identification and Classification of Inland Ports. *Centre for Transportation Research*. 0-4083-1 (5), 41-45.

Maharaj, A. (2013). Economic Development Position Paper on Port Expansion. EThekwini Municipality. 1 (6), 8-10.

Manda, S. (2015). Durban Dig-out Port. Available: http://www.iol.co.za/business/news/durban-dig-out-port-think-again-1821443 [Last accessed 15th Feb 2016].

Marine Traffic. (2017). *MSC Fabiola*. Available: http://www.marinetraffic.com/en/ais/details/ships/shipid:758455/mmsi:255805798/imo:9447847/vessel:MSC_FABIOLA [Last accessed 28th Jan 2017]

Mather, A.A & Reddy, K. (2008). Expansion plans for the Port of Durban. What are the issues for the city of Durban. M-05 (3), 3-5.

Monios, J. (2011). The role of inland terminal development in the hinterland access strategies of Spanish ports. Research in Transportation Economics. 33 (1): 59-66.

Moonsamy, I. (2016). Personal Communication, information for container yard capacity, Pier 2. Ivan.Moonsamy@transnet.net

MPoverello. (2013). *Johburg Chamber to meet Parliment over Customs Bill*. Available: http://mpoverello.com/2013/06/11/johburg-chamber-to-meet-parliment-over-customs-bill/ [Last accessed 1st March 2016]

Naidoo, D. Stippel, V. Henning, D. Maharaj, R. (2014). *Proposed Deepening, Lengthening and Widening of Berth 203 to 205, Pier 2, Container Terminal, Port of Durban*. Available: http://www.berth203to205expansioneia.co.za/documents/AmendedEIA/Amended%20EIR01I%20Moonsamy%20Berth%20203%20to%20205%20EIA%2003-06-14.pdf [Last accessed 2nd September 2016]

Nandkuar, A. (2016) . TEU data for the Port of Durban . Amit.Nandkuar@transnet.net

Presidential Infrastructure Coordinating Commision. (2013). A Summary of the South African National Infrastructure Plan. .. 1 (2-5), 10-38.

Preuss, D. (2015). *Africa's busiest port poised for expansion.*Available: http://www.bdlive.co.za/business/2015/05/18/video-africa-s-busiest-port-poised-for-expansion . [Last accessed 7th October 2016]

Porée, N. (2011). Durban-Johannesburg Rail Developments. Available: http://www.safti.co.za/?page_id=118 [Last accessed 11th March 2016].

Rodrigue, JP and Notteboom, T. (2013). A New Role for Inland Terminals. *Inland Ports/Dry Ports*. 3 (Chap 4), -

Rodrigue, JP (2013). *The Geography of Transport Systems*. New York: -. (3) 235-240.

Roso, V , Lumsden, K. (2009). The Dry Port Concept: Moving Seaport Activities Inland?. *Transport and Communications Bulletin for Asia and the Pacific*. 78 (1), 87-101

SA News. (2015). *Transnet completes R800m City Deep Terminal upgrade.* Available: http://www.sanews.gov.za/south-africa/transnet-completes-r800m-city-deep-terminal-upgrade [Last accessed 29th Feb 2016]

Smith, D. (2012). Container Port Capacity and Utilization Metrics.*Diagnosing the Marine Transportation System*. 1 (-), 1-24

The Tioga Group, Inc., 2006. Presentation: Inland Port Feasibility Study. [Online] Available at: http://www.tiogagroup.com [Last Accessed 23 Feb 2016].

TNPA (2015). *Regional Customer Conference.* Available: http://www.transnetnationalportsauthority.net/Corporate%20Affairs/Presentations/Strategic%20Customer%20Forum%20KZN%20Region%20ICC%20DBN%2027%20August%202015/Infra%20Customer%20Conference%2027%20August [Last accessed 1st September 2016]

TNPA. (2016). Port of Durban. Available: http://www.transnetnationalportsauthority.net/OurPorts/Durban/Pages/Overview.aspx [Last accessed 31 August 2016]

TNPA (2016). *Port of Durban. Location Map.* Available: http://www.transnetnationalportsauthority.net/OurPorts/Durban/Pages/Location-Map.aspx [Last accessed 31 August 2016]

Trainaviciute, L., 2009. The Dry Port - Concept and Perspectives. [Online] Available at: http://www.northsearegion.eu/files/repository/20130301142236_WPC-TheDryPortConcept.pdf [Last Accessed 23 Feb 2016].

Transnet (2014). -. Port Development Plan. 1 (4), 119-200.

Transnet Limited (2015). Annual Report 2015 (1), 75-100.

Transnet Limited, 2014. Annual Report 2014. (1), 88-104.

Transnet Limited, 2012. Annual Report 2012. (1), 88-104.

Transnet. (2012). *Durban Container Terminal*. Available: http://www.transnet-tpt.net/Ports/Pages/Durban_Container.aspx. Last accessed 19th Feb 2016

Transnet Group Planning. (2009). Rail Development Plans. Available: http://www.transnet.net/BusinessWithUs/TNInfrastructurePlan/NIP%20-%20Chapter%207f%20-%20Rail.pdf . [Last accessed 11th March 2016.]

Transport Information Service. (2015). Standard Containers. Available: http://www.tis-gdv.de/tis_e/containe/arten/standard/standard.htm [Last accessed 20th January 2017]

Tristan. (2015). SA ports getting smarter. Available: http://www.transportworldafrica.co.za/2015/07/09/sa-ports-getting-smarter/ . [Last accessed 8th November 2016]

UNCTAD. (1982) Multimodal transport and containerisation. TD/B/C.4/238/Supplement 1, Part Five: Ports and Container Depots. Geneva: United Nations Conference on Trade and Development.

Unescap. (2015). Container Trade Growth. . (3), 26-31

Unknown. (2015). Port of Durban. Available: http://www.worldportsource.com/ports/review/ZAF_Port_of_Durban_50.php . [Last accessed 20th Feb 2016]

Unknown. (2014). *Three of the World's Largest STS Cranes Arrived in Khalifa Port.* Available: http://worldmaritimenews.com/archives/102830/three-of-worlds-largest-sts-cranes-arrives-in-khalifa-port-uae/ [Last accessed 7th March 2016]

Unknown. (2015). *Virginia Inland Port (VIP).* Available: http://www.portofvirginia.com/facilities/virginia-inland-port-vip/ [Last accessed 29th Feb 2016]

Venter, I. (2016). South African container trade under pressure, reports show. Available: http://www.engineeringnews.co.za/article/shipping-2016-04-08 . [Last accessed 19th July 2016].

Appendix A Container projections for Durban Container Terminal

A.1 Monthly Container Throughput Projection

The monthly container throughput projection was developed by the author of this study and was based on actual monthly container volumes obtained from Nandkuar (2016), Buthelezi (2016).

The monthly throughput data was obtained and analysed from January 2014 through December 2015. The data was plotted and a linear trend line was plotted to project data for any future date, granted the throughput increases linearly.

Figure 51 shown below represents the above mentioned data, with the trend line visible.

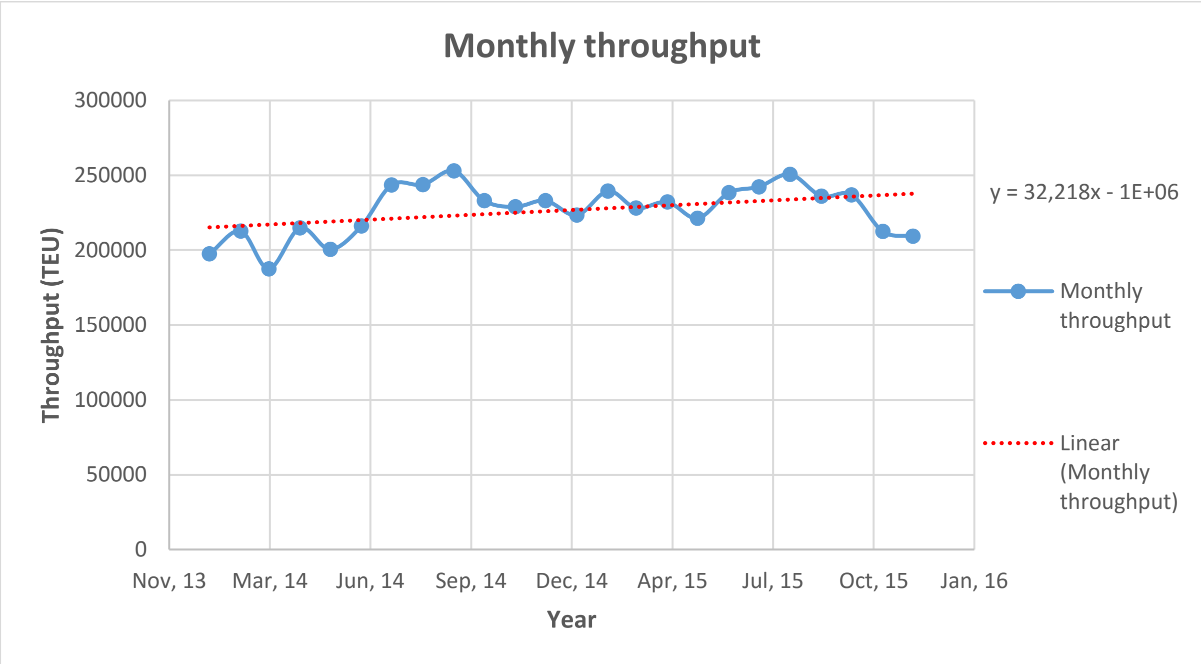


Figure 51- Monthly throughput data for DCT, adapted from Nandkuar and Buthelezi (2016)

The trend line, represented in red in Figure 51, was used to calculate yearly throughput projections based on actual throughput data. The forecast is presented in Figure 52:

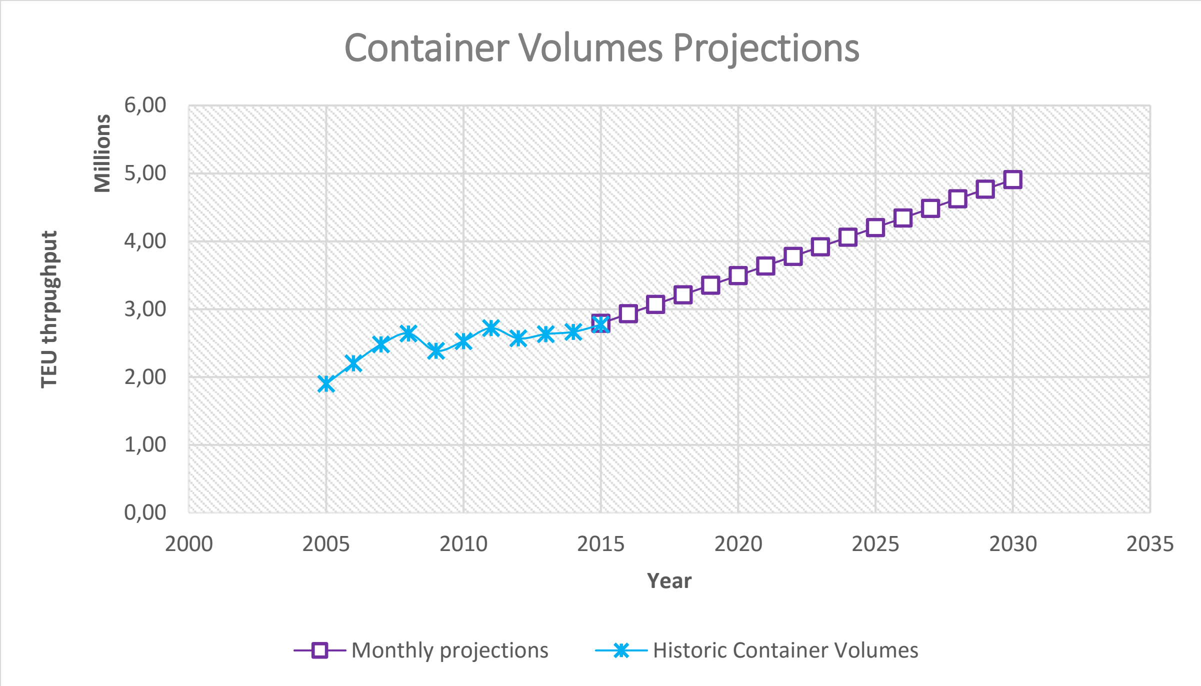


Figure 52 - Forecasted container throughput volumes

As represented above the forecast follows a linear projection. The researcher used this projection as it was predicted that the data would not increase exponentially.

A.2 Constant Growth Rate Forecast

To compare the above mentioned forecasts the author of this study compiled a forecast method which implements constant growth rates on historic container throughput data.

Unescap (2015) indicated that the global container volumes growth rate was around 6.5% from the year 2005. In the light of the capacity and spatial constraints the author of this study decided to do forecasts that follow a three and five percent (3-5%) growth rate. Table 25 shows the throughput data for a 3% and 5% growth rate:

Table 25 - Container Volume Forecast for Constant Growth Rate

Year	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***
Constant 3% growth (mil TEU)	2,7703	2,85345	2,93905	3,02722	3,11804	3,21158	3,30792
Constant 5% growth (mil TEU)	2,77034	2,9089	3,0543	3,207	3,36736	3,535	3,712

The above data was presented graphically in Figure 53, which shows the historical data along with the forecasted throughput projections:

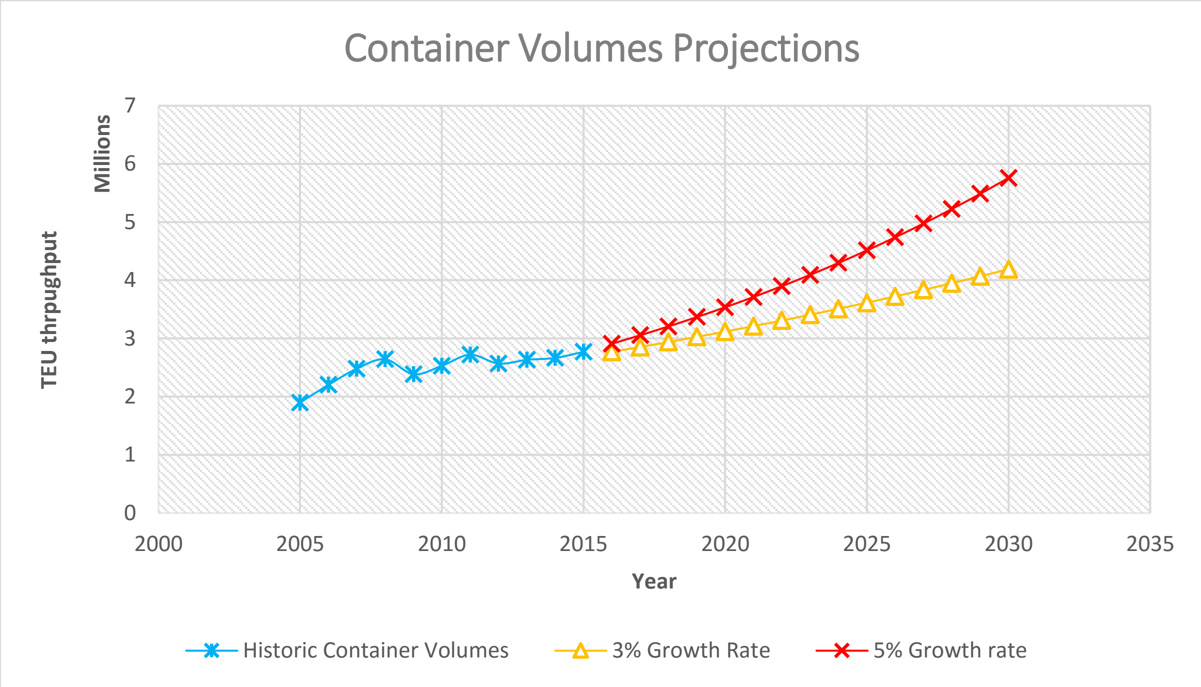


Figure 53 - Container Forecast for Constant Growth Rates

Appendix B – Capacity Limiting Constraints - Calculations

B.1 Transhipment Calculation

This appendix shows the calculation used to determine the transhipment percentage for the Port of Durban. The value was calculated by taking the average of transhipped containers for imports and exports, for the years 2010-2014.

Table 26 - Values used to calculate transhipment

	2009-2010			2010-2011			2011-2012			2012-2013			2013-2014			2014-2015		
	FULL	EMPTY	TOTAL	FULL	EMPTY	TOTAL	FULL	EMPTY	TOTAL	FULL	EMPTY	TOTAL	FULL	EMPTY	TOTAL	FULL	EMPTY	TOTAL
IMPORT																		
DEEPSEA	766 209	163 868	930 077	928 786	114 132	1 042 918	1 019 321	94 716	1 114 037	1 042 641	89 927	1 132 568	1 035 632	114 054	1 149 686	1 036 663	126 327	1 162 990
COASTWISE	5 049	5 430	10 479	3 503	8 461	11 964	2 802	4 377	7 179	2 693	3 396	6 089	4 185	3 658	7 843	4 290	1 918	6 208
TRANSHIPPED	233 654	56 984	290 638	208 849	33 734	242 583	209 533	42 090	251 623	121 955	22 942	144 897	127 235	40 172	167 407	154 199	61 009	215 208
TOTAL LANDED	1 004 912	226 282	1 231 194	1 141 138	156 327	1 297 465	1 231 656	141 183	1 372 839	1 167 289	116 265	1 283 554	1 167 052	157 884	1 324 936	1 195 152	189 254	1 384 406
EXPORT																		
DEEPSEA	607 794	276 910	884 704	634 656	367 767	1 002 423	625 500	426 814	1 052 314	630 370	450 235	1 080 605	708 800	420 245	1 129 045	677 848	454 172	1 132 020
COASTWISE	14 710	12 452	27 162	11 875	12 048	23 923	14 093	10 858	24 951	11 246	9 507	20 753	12 218	21 033	33 251	11 913	16 123	28 036
TRANSHIPPED	237 787	56 184	293 971	211 568	37 071	248 639	201 912	46 157	248 069	121 953	22 540	144 493	133 081	39 833	172 914	153 013	59 999	213 012
TOTAL SHIPPED	860 291	345 546	1 205 837	858 099	416 886	1 274 985	841 505	483 829	1 325 334	763 569	482 282	1 245 851	854 099	481 111	1 335 210	842 774	530 294	1 373 068
GRAND TOTAL	**1 865 203**	**571 828**	**2 437 031**	**1 999 237**	**573 213**	**2 572 450**	**2 073 161**	**625 012**	**2 698 173**	**1 930 858**	**598 547**	**2 529 405**	**2 021 151**	**638 995**	**2 660 146**	**2 037 926**	**719 548**	**2 757 474**

Table 26 was used to calculate the transhipment percentage for the DCT. This was achieved by dividing the number of transhipped containers by the total number of containers for import and export separately. Table 27 shows the values for transhipment.

Table 27 - Transhipment Percentage Values

	Transhipment %		
Year	**Import**	**Export**	**Combined**
2009-2010	23.61%	24.38%	23.99%
2010-2011	18.70%	19.50%	19.10%
2011-2012	18.33%	18.72%	18.52%
2012-2013	11.29%	11.60%	11.44%
2013-2014	12.64%	12.95%	12.79%
2014-2015	15.55%	15.51%	15.53%

It was found that the transhipment percentage for the DCT decreased from 24% in 2009 to around 15% in 2015. This is due to the Port of Ncqura that opened in 2011/2012, which decreased the number of containers transhipped from the DCT to Ncqura. The researcher A value of **15% Transhipment** was assumed for the DCT.

B.2 Peak Factor

The peak factor was calculated by dividing the peak terminal throughput/month by the average throughput for each month. The data that was used was monthly throughput data for 2014 and 2015, provided by Nandkuar (2016). The formula used can be seen below, Bestenbreur (2015):

$$Peak\ factor = \frac{Peak\ Terminal\ Throughput\ (TEU\frac{moves}{month})}{Average\ Terminal\ Throughput\ (TEU\frac{moves}{month})} \qquad \text{Equation 9}$$

Table 28 - Calculation of Peak Factor

Characteristic	***2014***	***2015***
Peak Terminal Throughput (TEU moves/month)	252 978	250 616
Average Terminal Throughput (TEU moves/month)	222 028	230 861
PF – Peak Factor	1.14	1.09

From Table 28 above it can be seen that the actual Peak Factor is close to one. For a conservative approach a **Peak factor of 1.1** will be used for calculation purposes. This was done to account for large peaks that have been experienced in years prior to 2014.

B.3 Important Capacity Characteristics of Current Terminal

This section calculates three important container throughput constraints that have a direct impact on the overall terminal efficiency.

B.3.1 Container Crane Capacity

The container crane capacity was calculated for both Pier 1 and Pier 2 for the DCT. The calculation shows the number of TEU that the cranes can physically handle in a year. This gives an indication of whether the cranes are a capacity limiting constraint. The following formula was used to calculate the container crane capacity:

$$\begin{aligned} &Annual\ Container\ Crane\ Capacity\ (TEU) \\ &\qquad = no.of\ container\ cranes \times working\ hours \\ &\qquad \times container\ moves\ per\ hour \times TEU factor \end{aligned}$$

Equation 10

Table 29 shows the variables used to calculated the annual container crane capacities for Pier 1 and Pier 2 respectively.

Table 29 - Annual Container Crane Capacity for DCT

Characteristic	***Pier 1***	***Pier 2***
Number of container cranes	6	16
Working hours	5212.8	5212.8
Crane productivity (Cont. moves/hour)	25	25
TEU factor	1.6	1.6
Total Container Crane Capacity (TEU moves/year)	**1 251 072**	**3 336 192**

B.3.2 Rail/Truck Terminal Capacity

The way that containers enter/leave a port forms a crucial part of achieving a high yearly throughput. The rail/road terminals must be able to handle the throughput that the container yard achieves in an efficient manner. The two terminals, Pier 1 and Pier 2, will be analysed separately and will then be compared with the other constraints.

Figure 54 shows the truck and rail terminals that the Port of Durban has.

Figure 54 - Rail terminals and truck loading bays for DCT, Google Earth (2016)

Figure 54 shows the truck loading bays and rail terminals that the DCT has for receiving and distributing of containers. The rail and truck terminal capacity will be calculated for each pier, which will then be compared to the other capacities analysed in this section.

B.3.2.1 Pier 1

Rail Terminal

It was found that Pier 1 has one dedicated rail terminal which serves the pier. The rail terminal has 3 tracks, and can serve trains of 750m in length. The terminal currently has one RTG crane operating.

Figure 55 shows the current rail terminal for Pier 1.

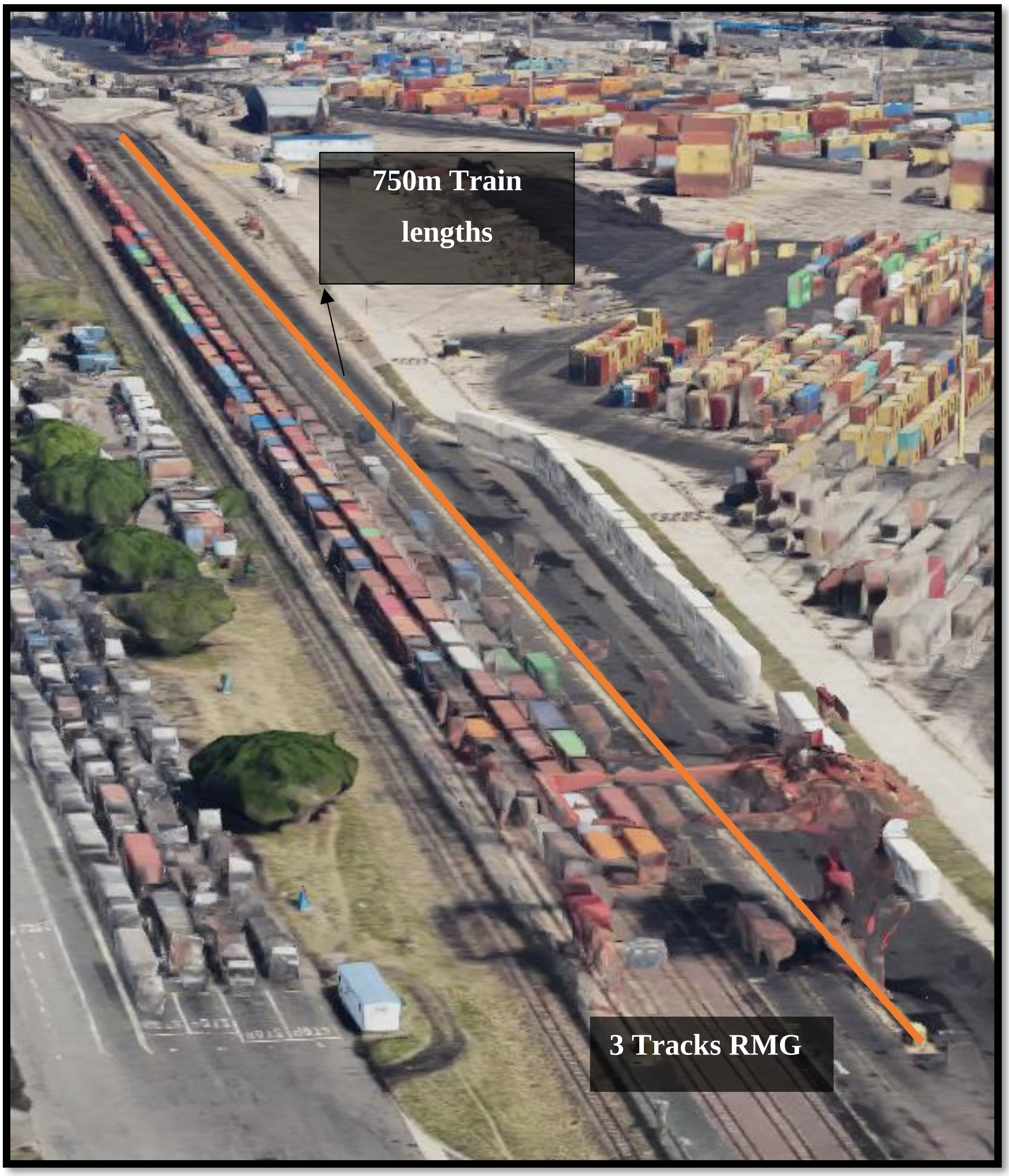


Figure 55 - Rail Terminal for Pier 1

Figure 55 shows the rail terminal that is currently serving the Pier 1 terminal. It was measured that the terminal can handle three trains of up to 750m. The average train turnaround time stated by Transnet Limited (2015) was 3 hours. The trains have to be loaded and offloaded and thus a turnaround time of 5 hours was assumed.

The calculation will follow the formula shown by Equation 11.

$$Total\ Rail\ Capacity\left(TEU\frac{moves}{year}\right)$$
$$= (Number\ of\ trains\ per\ day\ per\ track)\times(No.tracks)$$
$$\times(Working\ days)\times\left(Max\ no.\frac{TEU}{train}\right)\times Operational\ factor$$

Equation 11

The above formula was used to calculate the container throughput that the rail terminal could handle. The number of trains per day is dependant on the average train turnaround time for the terminal. It was assumed that the terminal operates for 24 hours a day, as stated by Transnet (2014). The operational factor makes provision for downtime and that the terminal cannot operate at max capacity at all times.

The calculation for the rail capacity can be seen in Table 30.

Table 30 - Rail terminal capacity calculation

Characteristic	***Pier 1***
Max train length (m)	750
Train Turnaround Time (hours)	5
No. trains per track/day	4.8
No. of tracks	3
Max TEU/train = (Max Train length/14m per wagon) x 2 TEU/wagon	103
Working days (days/year)	362
Operational factor	0.7
Rail Terminal Capacity (TEUs/year)	**377 478**

The throughput that the RMG crane could handle was calculated as follows:

$$RMG\ Container\ Throughput\ \left(TEU\frac{moves}{year}\right) = \left(RMG\ productivity\ Cont.\frac{moves}{hour}\right) * Working\frac{hours}{year} * TEUfactor$$

Equation 12

The formula shown in Equation 12 was used to calculate the container throughput that the one RMG crane could handle annually. Table 31 shows the variables and calculation mentioned above:

Table 31 - Calculation for RMG throughput

Characteristic	***Value***
RMG productivity (cont.moves/hour)	15
*Working hours per year (20 hours/day * 362 days)*	7240
TEU factor	1,6
RMG Container Throughput (TEU moves/year)	**173 760**

From this calculation it can be seen that the single RMG crane operating on the rail terminal for Pier 1 is not sufficient to handle the throughput that the rail terminal handles.

Truck Terminal

It was found that Pier 1 is currently being served by two truck loading terminals. The first truck terminal contains 10 loading lanes, for which one truck can be loaded/offloaded per lane at a time. The second terminal contained 8 loading lanes, where one truck can be loaded/offloaded per lane at a time.

Figure 56 shows the two truck terminals serving Pier 1.

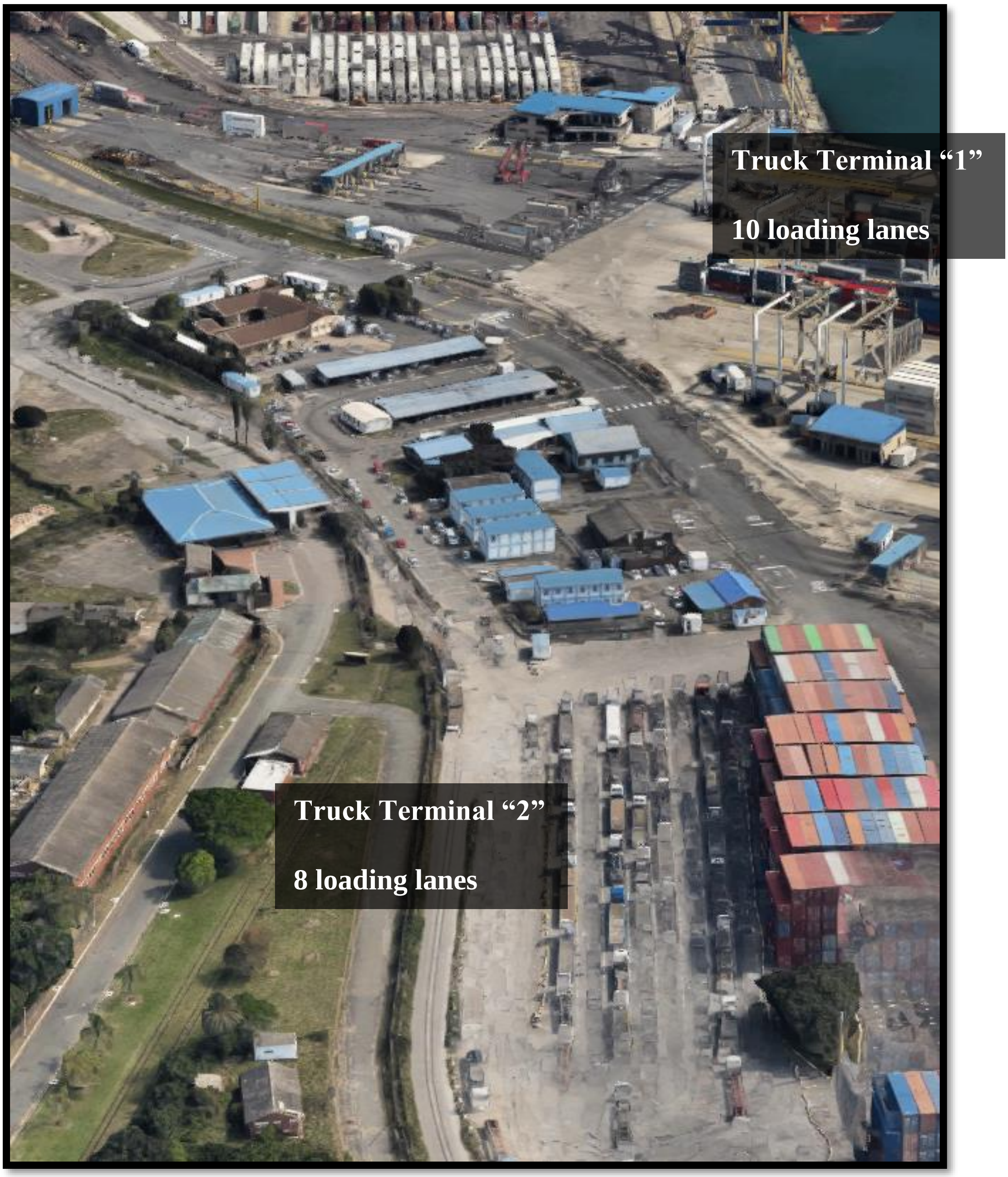


Figure 56 - Truck Terminals for Pier 1, Google Earth (2016)

Figure 56 shows the layout of the two truck terminals that serve Pier 1. The formula that was used to calculate the truck terminal capacity is represented by Equation 13:

$$Truck\ Terminal\ Capacity\ \left(TEU\,\frac{moves}{year}\right) = (No.\,truck\ lanes)\times(No.\,of\ trucks\ per\ day) \times(No.\,containers\ per\ truck)\times(TEU\ factor)\times\left(Working\,\frac{days}{year}\right) \times Operational\ factor$$

Equation 13

The number of trucks per day is based on the average truck turnaround time. The average truck turnaround time was taken as 15 min, which is a conservative turnaround time. An assumption was made that the terminals operate 24 hours a day. Thus no. trucks per day = 24/Average truck turnaround time. The calculation for the truck terminal capacities is shown in Table 32.

Table 32 - Truck Terminal Capacity, Pier 1

Characteristic	***Truck Terminal 1***	***Truck Terminal 2***	***Pier 1 Total***
Average truck turnaround time (hours)	0.25	0.25	
No. loading bays	10	8	
Max no. trucks per bay/day	96	96	
No. containers per truck	1	1	
TEU factor	1.6	1.6	
Working days (days/year)	362	362	
Operational factor	0.8	0.8	
Truck Terminal Capacity (TEUs/year)	**444 826**	**355 860**	**800 686**

Combined Rail and Truck Capacity

This section analysed the rail and truck terminal capacities for Pier 1. The capacities were calculated in terms of TEU's/year and could thus be compared to the other capacity constraints for the Port of Durban.

The rail and road capacities are shown in Figure 57.

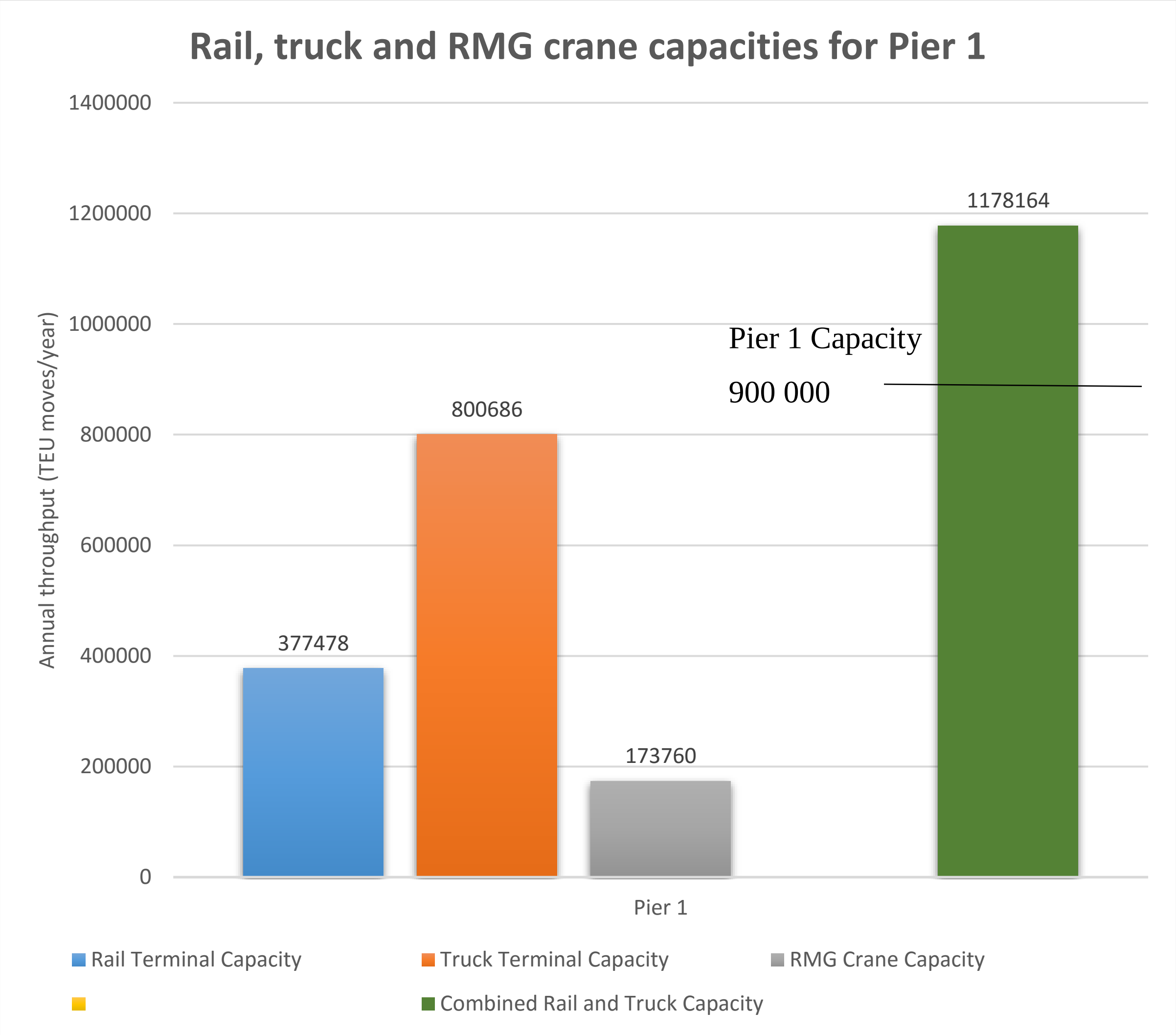


Figure 57 - Rail and Truck Terminal Capacities, Pier 1

Figure 57 was analysed and the following was concluded:

- Pier 1 has sufficient road and rail terminals to handle the current container throughput
- . The rail terminal requires at least one additional RMG crane. This was due to the single RMG crane not being sufficient to handle the yearly container throughput that the terminal can generate.
- It is recommended that the rail terminal be upgraded by adding two RTG cranes.

B.3.2.2 Pier 2

Rail Terminal

The same procedure was followed for Pier 2. It was found that the terminal was served by one dedicated rail terminal, which contained 3 tracks that were operated by 3 rail mounted gantry (RMG) cranes, and three tracks which used for loading with reach stackers.

Figure 58 shows the rail terminal for Pier 2.

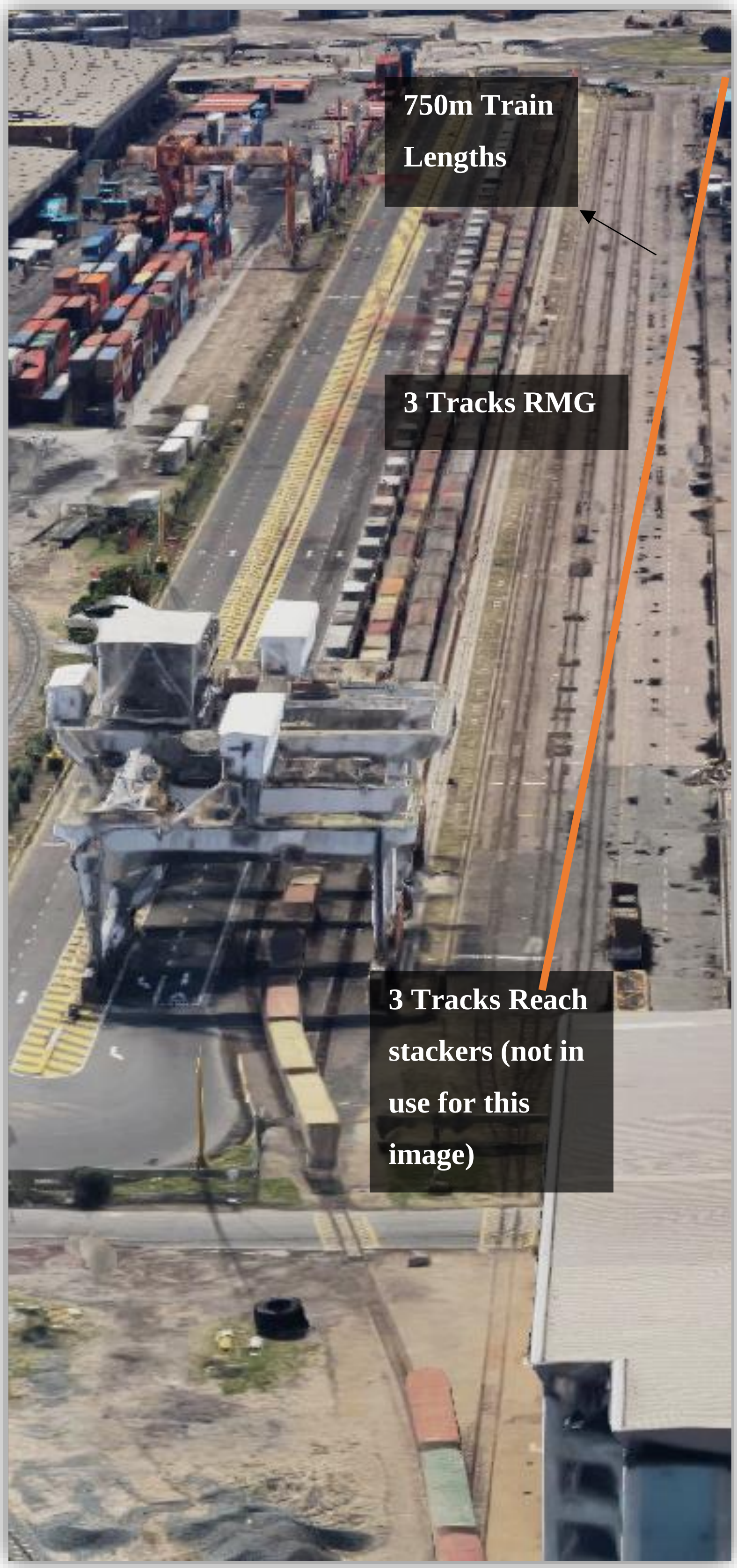


Figure 58 - Rail Terminal for Pier 2, Google Earth (2016)

Figure 58 shows the layout of the rail terminal for Pier 2. The calculation for the capacity of the rail terminal followed the same procedure as for Pier 1. The formula used was stated by Equation 13 and is shown:

$$Total\ Rail\ Capacity\left(TEU\frac{moves}{year}\right)$$
$$= (Number\ of\ trains\ per\ day\ per\ track)\times(No.tracks)$$
$$\times(Working\ days)\times\left(Max\ no.\frac{TEU}{train}\right)\times Operational\ factor$$

The number of trains per day is dependant on the average train turnaround time, which was stated by Transnet Limited (2015) to be 3 hours for Pier 1 and Pier 2. The train turnaround time was assumed to be 5 hours, the terminal handles containers getting loaded and offloaded. It was assumed that the terminal operates for 24 hours a day, 362 days a year. X shows the calculation for the rail terminal capacity for Pier 2.

Table 33 - Rail terminal capacity calculation, Pier 2

Characteristic	***Pier 2***
Max train length (m)	750
Train Turnaround Time (hours)	5
No. trains per track/day	4.8
No. of tracks	6
Max TEU/train = (Max Train length/14m per wagon) x 2 TEU/wagon	103
Working days (days/year)	362
Operational factor	0.7
Rail Terminal Capacity (TEUs/year)	**754 957**

The rail terminal at Pier 2 has 3 RMG cranes serving it, and thus the throughput that these cranes can handle was calculated. Equation 12 was used to calculate the throughput for one

RMG crane, and was thus multiplied by 3 to acquire the container throughput that is achieved by the cranes operating on the rail terminal for Pier 2.

Table 34 shows the container throughput that the RMG cranes can handle at Pier 2:

Table 34 - RMG container throughput for Pier 2

Characteristic	***Value***
RMG productivity (cont.moves/hour)	15
*Working hours per year (20 hours/day * 362 days)*	7240
TEU factor	1,6
Number of cranes	3
RMG Container Throughput (TEU moves/year)	**521 280**

It was observed that the rail container throughput exceeds the throughput that the RMG cranes can handle. It is thus recommended that an additional RMG crane is added to the terminal.

Truck Terminal

From an analysis of an aerial image it was established that Pier 2 was being served by two truck loading terminals. The two terminals are similar size and handle all containers that were shipped via road transport. The first truck terminal contains 35 loading bays, which handle one truck at a time, per bay. The second truck loading terminal contains 33 loading bays, which can handle one truck per bay at one time.

Figure 59 shows the two truck loading terminals that serve Pier 2.

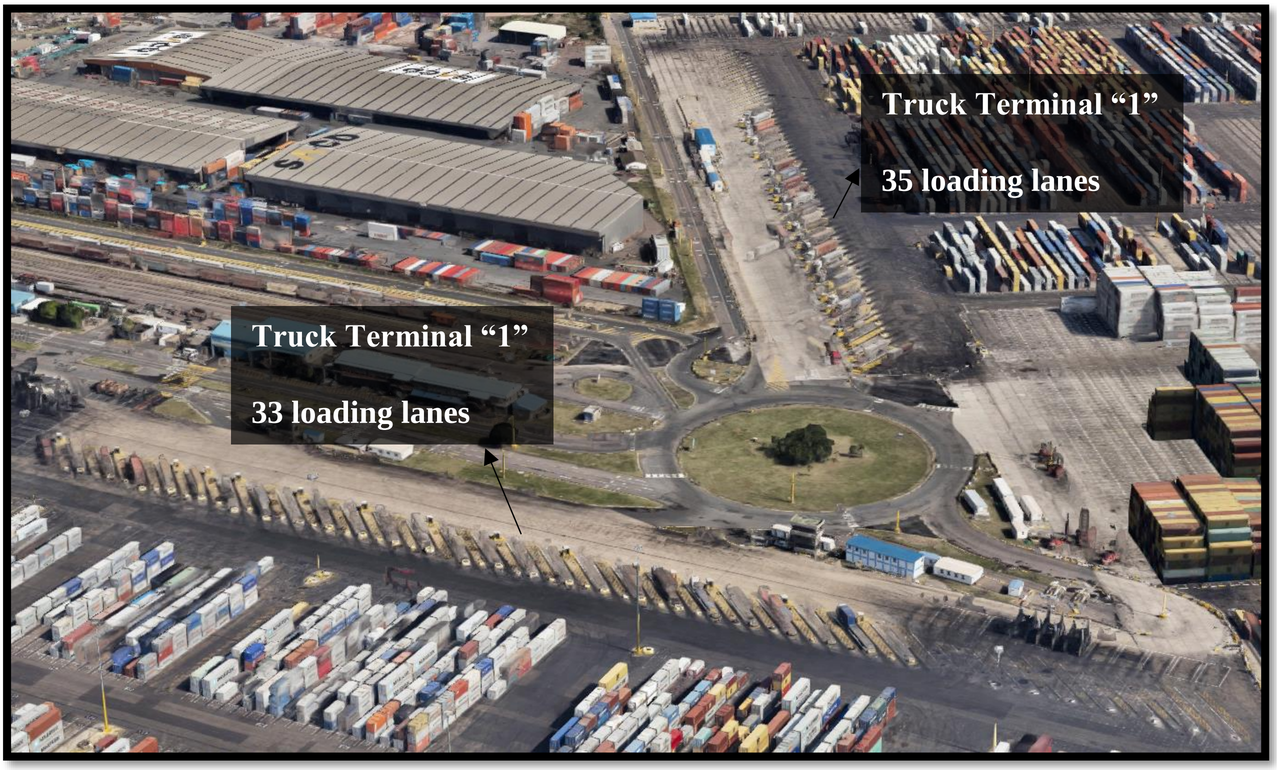


Figure 59 - Truck Loading Terminals for Pier 2, Google Earth (2016)

Figure 59 shows the two truck terminals for Pier 2. The truck turnaround time is crucial for the calculation of the terminal capacity, and was stated by Transnet Limited (2014) to be 38 min for 2014, and Transnet Limited (2015) stated 5 min for 2015. The formula used to calculate the truck terminal capacity and is shown below:

$$Truck\ Terminal\ Capacity\ \left(TEU\frac{moves}{year}\right)$$
$$= (No.truck\ lanes)\times(No.of\ trucks\ per\ day)$$
$$\times(No.containers\ per\ truck)\times(TEU\ factor)\times\left(Working\frac{days}{year}\right)$$
$$\times Operational\ factor$$

The number of trucks per day is based on the average truck turnaround time. The average truck turnaround time stated by Transnet Limited (2015) was 5 min for the year 2015, however a turnaround time of 15min was used as a conservative approach. An assumption was made that the terminals operate 24 hours a day. Thus no. trucks per day = 24/Average truck turnaround time. The calculation for the truck terminal capacities is shown in Table 35.

Table 35 - Calculation for Truck Terminal Capacity, Pier 2

Characteristic	Truck Terminal 1	Truck Terminal 2	Pier 2 Total
Average truck turnaround time (hours)	0.250	0.250	
No. loading bays	35	33	
Max no. trucks per bay/day	96.0	96.0	
No. containers per truck	1	1	
TEU factor	1.6	1.6	
Working days (days/year)	362	362	
Operational factor	0.8	0.8	
Truck Terminal Capacity (TEUs/year)	**1 556 890**	**1 467 924**	**3 024 814**

Combined Rail and Truck Capacity

This section analysed the rail and truck terminal capacities for Pier 1. The capacities were calculated in terms of TEU's/year and could thus be compared to the other capacity constraints for the Port of Durban.

The rail and road capacities for Pier 2 are shown in Figure 60.

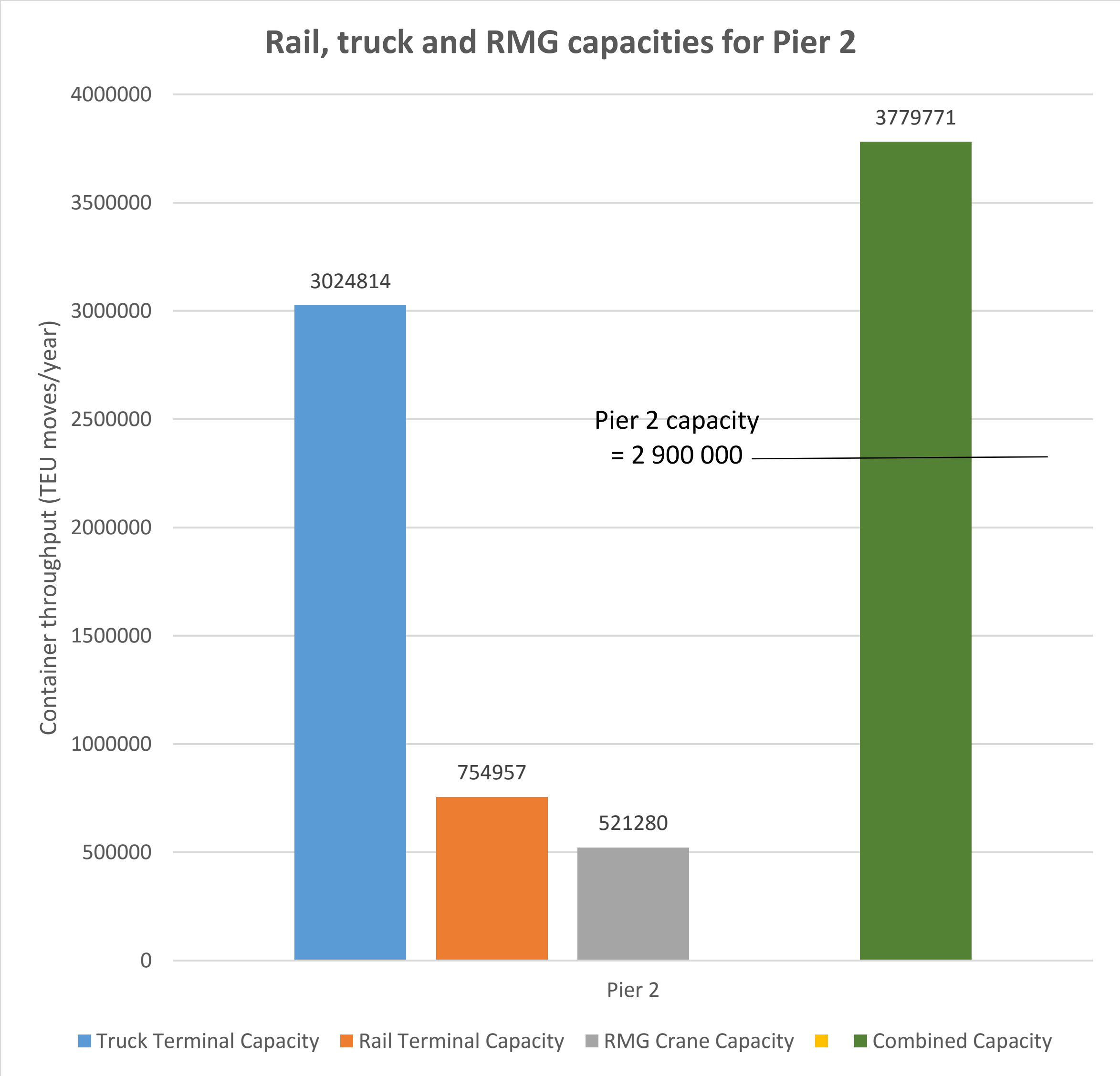


Figure 60 - Rail and Truck Terminal Capacity, Pier 2

Figure 60 was analysed and the following conclusions were made:

- The combined rail and truck terminal capacities are sufficient to distribute or receive the container throughput that the port can handle.
- It was noted that the container throughput that the RMG cranes can handle is less than the rail terminal capacity. Thus the terminal should add an additional RMG crane.

Appendix C – Bayhead Road Dry Port calculations

This Appendix includes the calculations related to the Bayhead Road dry port which include: number of trains/tracks required for the shuttle train and hinterland rail terminals; number of loading bays for truck terminal; number of ground slots required for import and export stacks.

C.1 Shuttle Train Terminal

The following characteristics were used for the calculation of the number of trains/tracks that the shuttle train requires:

Table 36 - Characteristics for shuttle train

Characteristic	*Value*	*Source*
Train lengths	750 m	Assumption by researcher
Number of Containers per train	= 48 wagons, 2 TEU per wagon =96 TEU per train =60 Containers per train	
DCT max capacity after expansions + Pier 2 to RTG (Chapter 7.2)	7 100 000 TEU moves/year	Calculated by researcher
Percentage of containers going to/from Bayhead Road "transfer centre"	60%	Assumption by researcher
Number of TEU/year using shuttle train	= 7 100 000 * PF*(1-Tr%) * 0.6 = 7 100 000 *1.1 * 0.85*0.6 =3 983 100 TEU moves/year	
Number of Container moves/year using shuttle train	=3 983 100 / TEUfactor = 3 983 100/1.6 = 2 489 438 Cont moves /year	
Number of Container moves/day using shuttle train	= 2 489 438/365 = 6820 Containers /day	
Thus:	3410 Containers to Bayhead Road/day 3410 Containers from Bayhead Road/day	
Number of train loads required per day	= 3410/60 containers per train = 57 train loads	

The next step was to calculate the train turnaround time between the DCT and the Bayhead Road "transfer centre". The following sequence was used to calculate the train turnaround time:

1. • Loading 60 Cont. at DCT
2. • Travel to Bayhead Road
3. • Offload 60 Cont. at Bayhead Road
   • Load 60 Cont. at Bayhead Road
4. • Travel back to DCT
5. • Offload 60 Cont. at DCT

Table 37 shows the calculation for the average train turnaround time between the Bayhead Road "transfer centre" and the DCT:

Table 37 - Train Turnaround time for Shuttle Train between DCT and Bayhead Road "transfer centre"

Description	***Time taken***	***Comment***
Loading 60 Cont. at DCT	1hr	3 RMG cranes at 20 Cont. moves/gch
Travel to Bayhead Road	5min	
Offload 60 Cont at Bayhead Road.	1 hr	3 RMG cranes at 20 Cont. moves/gch
Loading 60 Cont.	1hr	As above
Travel back to DCT	5min	
Offload 60 Cont.	1 hr	As above
Inefficiencies	2 hours	Delays are often experienced
Total Train Turnaround Time	**6hr 10min**	

The number of track required for the shuttle train terminal was calculated as follows:

$$No. of\ trips\ per \frac{train}{day} = \frac{24hrs}{6\ hours\ 10\ min} = 3.89\ , Take\ 3\ trips$$

$$No. of\ required\ trains = 57\ train\ loads\ \div 3 =\ 19\ trains, doing\ 3\ trips\ per\ day$$

$Assume\ 3\ trains\ make\ use\ of\ 1\ track\ thus:$

$No. of\ tracks\ required \frac{19}{3} = 6.3$

$Thus: \quad 6\ tracks\ are\ sufficient\ for\ 19\ trains\ doing\ 3\ trips\ per\ day$

C.2 Hinterland Rail Terminal

It was calculated that the shuttle train service requires 6 tracks for loading/off loading. Due to the dedicated shuttle train service that would operate between the DCT and the Bayhead Road "transfer centre", **two rail terminals were designed**. One terminal would serve the shuttle trains, and the other would serve all containers that arrive/depart the Bayhead Road "transfer centre" to/from the hinterland. It was assumed that the Bayhead Road would handle **60% of the total containers going to/from the DCT**. In addition it was assumed that the hinterland rail terminal would handle **60%** of the import and export containers going through the Bayhead Road "transfer centre".

The calculation follows the same procedure that was followed for the shuttle trains. The characteristics for the hinterland terminal is as follows:

Table 38 - Characteristics for Hinterland Rail Terminal - Bayhead Road "transfer centre"

Characteristic	*Value*	*Source*
Train lengths	750 m	Assumption by researcher
Number of Containers per train	= 48 wagons, 2 TEU per wagon =96 TEU per train =60 Containers per train	
DCT max capacity after expansions + Pier 2 to RTG (Chapter 7.2)	7 100 000 TEU moves/year	Calculated by researcher
Percentage of containers going to/from Bayhead Road "transfer centre"	60%	Assumption by researcher
Modal Split	60% Rail 40% Truck	Assumption by the researcher
Number of TEU/year using shuttle train	= 7 100 000 * PF*(1-Tr%) * Modal Split% * 0.6 = 7 100 000 *1.1 * 0.85*0.6 =2 389 860 TEU moves/year	

Number of Container moves/year using shuttle train	= 2 389 860/ TEUfactor = 2 389 860/1.6 = 1 493 663 Cont moves /year
Number of Container moves/day using shuttle train	= 1 493 663/365 = 4092 Containers /day
Thus:	2046 Containers to Bayhead Road from hinterland/day 2046 Containers from Bayhead Road to hinterland/day
Number of train loads required per day	= 2046/60 containers per train = 34 train loads

The train turnaround time for the hinterland rail terminal was calculated as follows:

Table 39 - Train Turnaround time for hinterland rail terminal

Description	***Time taken***	***Comment***
Offloading 60 containers at Bayhead Road	1hr	3 RMG cranes at 20 Cont. moves/gch
Loading 60 containers at Bayhead Road.	1 hr	3 RMG cranes at 20 Cont. moves/gch
Inefficiencies	2hr	Shunting, downtime
Total Train Turnaround Time	**4 hours**	

The number of track required for the hinterland rail terminal was calculated as follows:

$No. of\ required\ trains = 34\ trains\ doing\ 1\ trip\ per\ day\ (assumed\ due\ to\ long\ distances)$

$Assume\ 7\ trains\ make\ use\ of\ 1\ track\ due\ to\ long\ distances\ that\ trains\ travel\ thus:$

$$No. of\ tracks\ required \frac{34}{7}$$

$$= 5\ tracks\ are\ sufficient\ for\ 34\ trains\ to\ arrive - offload - load - leave$$

C.3 Truck Loading Terminal

The formula that was used to calculate the number of loading bays was as follows: The maximum number of containers through the truck terminal per year was calculated by taking the total max capacity multiplied by 0.6 (Bayhead Road handles 60% of total containers - assumption), multiplied by 0.4 (40% modal split)

$$No.\,of\ truck\ loading\ bays$$
$$= \frac{(\,Max\ No.\,containers\ per\ year\ through\ terminal) * (1 - Tr\%) * PF}{(No.\,trucks\ per\ day\,) * (No.\,containers\ per\ truck) * \left(Working\,\frac{days}{year}\right) * Operational\ factor}$$

$$= \frac{\left(\frac{(7\,100\,000 * 0.85)}{1.6} * 0.6 * 0.4\right) * 1.1}{\left(\frac{24}{0.25}\right) * (1) * (365) * 0.8}$$

$$= 36$$

From the calculation, it was noted that the truck terminal on the Bayhead Road “transfer centre” would require 36 loading bays.

C.4 Ground slots for Import and Export Stacks

The number of ground slots was calculated using Bestenbreur (2015) formulas stated in Chapter 5.4 – Equation 2-4. The same assumption was made that the Bayhead Road "transfer centre" would handle 60% of the total import and export containers that are coming/going to the DCT, and that the split between import and export was 50%. The dwell time was assumed to be 7 days, due to containers dwelling in the DCT for a period of 4.5 days. It was also assumed that the Bayhead Road "transfer centre" would be served by a RTG "1 over 5" and tractor/trailer system. The number of ground slots for the import and export stacks were calculated separately, and can be seen in Table 40

Table 40 - Ground slots calculation for Bayhead Road "transfer centre"

Characteristic	***Unit***	***Import Stack***	***Export Stack"***
Transhipment	%	15	15
PF- Peak factor	-	1.1	1.1
TEU Factor	-	1.6	1.6
Dwell time	days	7	7
Max. effective stacking height	Containers	5	5
Average stacking height	Containers	3.5	3.5
n1 = Average stacking height/Max. Effective stacking height	-	0.7	0.7
n3 = Ground slots Utilized/Ground slots available	-	0.9	0.9
Q(di) + Q(lo)	Cont. moves/year	1 331 250	1 331 250
Container Stacking Yard Capacity	TEU moves/year	7 100 000*0.6*0.5 =2 130 000	=2 130 000
Required number ground slots	**-**	**13 200**	**13 200**

C.4.1 Stacking Module

A stacking module needs to be established. The stacking module ensures an efficient calculation of the number of ground slots required.

Figure 61 shows the stacking module that was chosen.

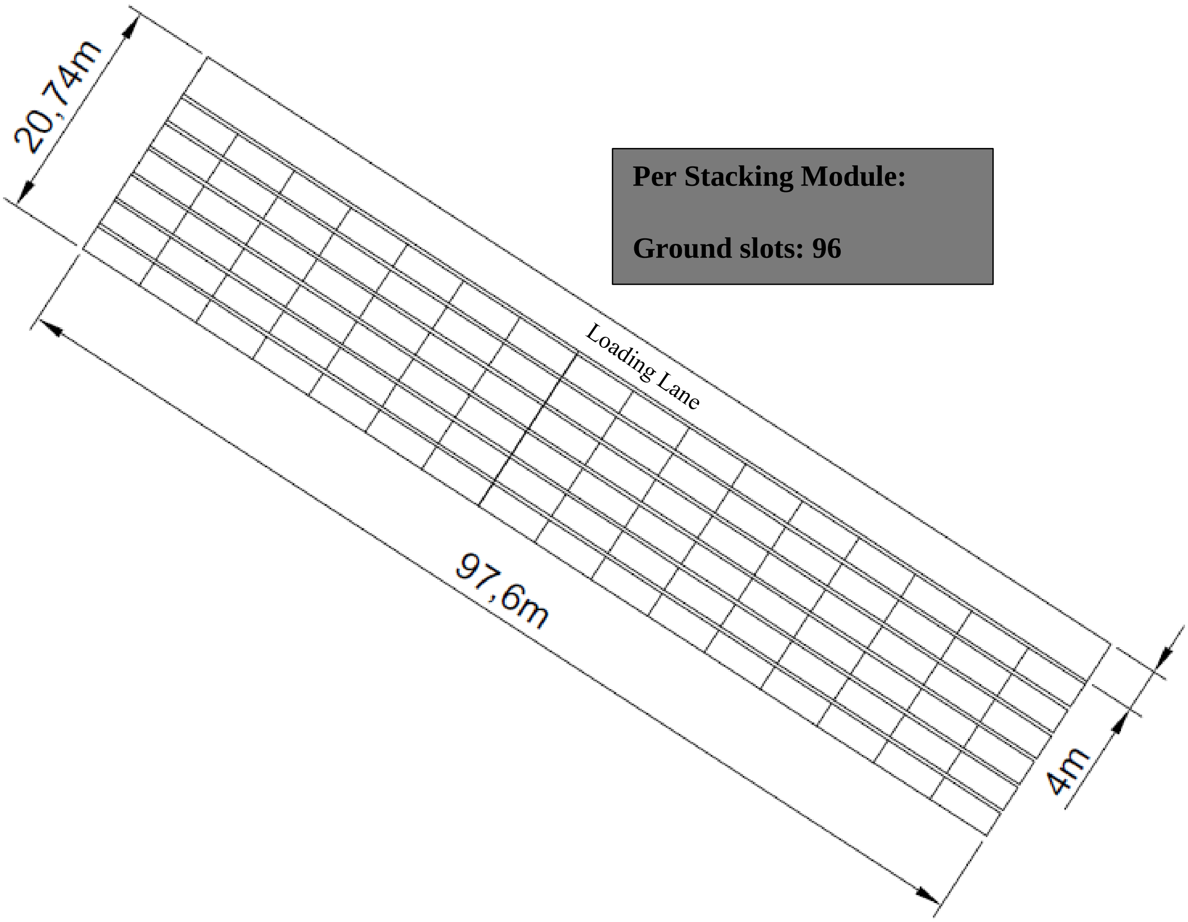


Figure 61 - Stacking Module for proposed dry port

Figure 61 shows that the above module yields **96 TEU ground slots**. To handle the proposed throughput, it was calculated that the import and export stacks for the Bayhead Road “transfer centre” **require 138 stacking modules each**. Each module would be served **by one RTG crane**.

C.5 Layout of Bayhead Road site

The design of the dry port was performed on AutoCad and the final overall layout can be seen in Figure 62.

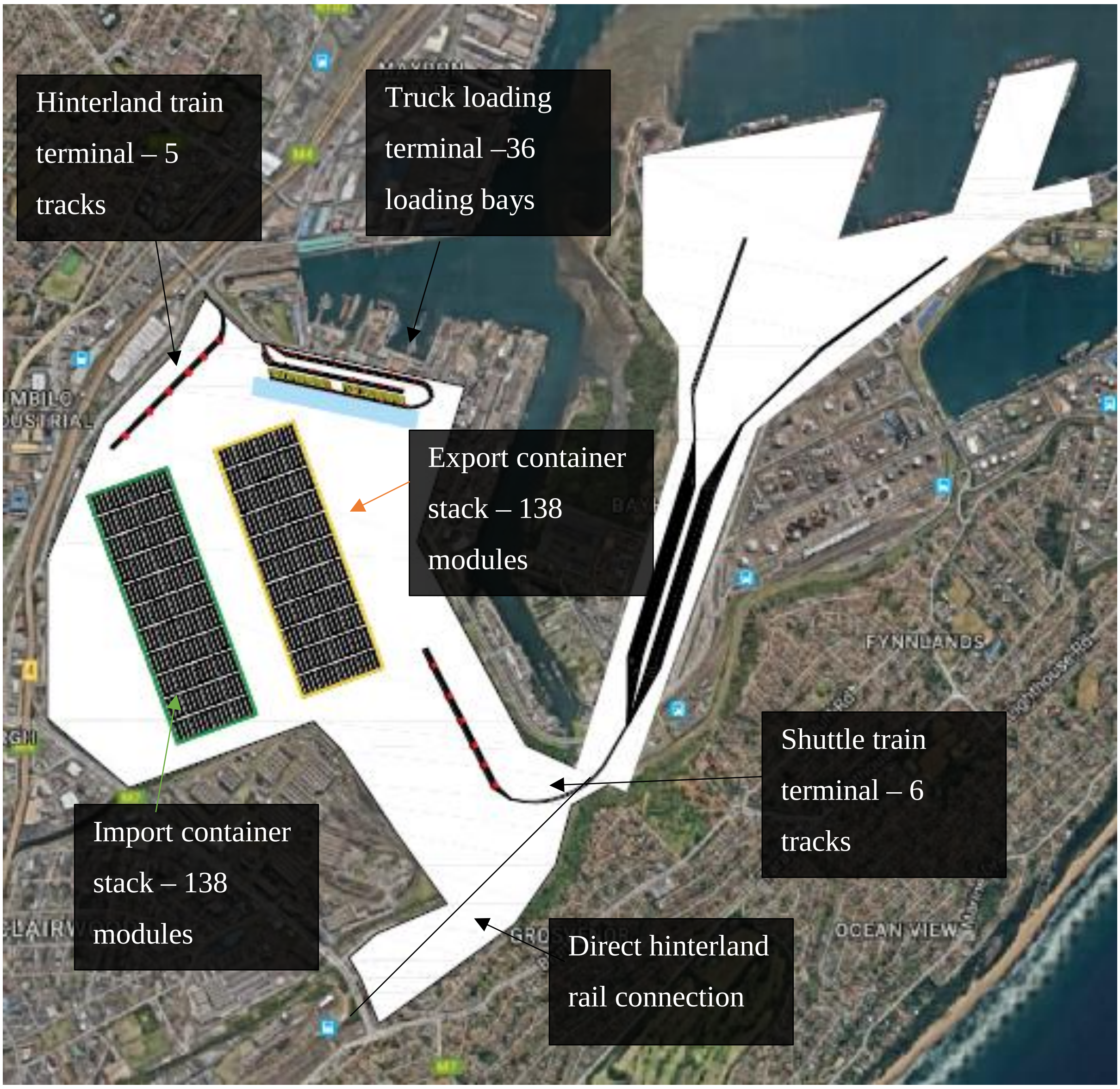


Figure 62 - Layout of Bayhead Road site, adapted from Google Earth (2016)

Appendix D: Old Durban Airport Dry Port calculations

This section shows the calculations that were performed for the design of a dry port on the old Durban Airport site.

D.1 Location of Proposed Dry Port

Two locations have been identified to be feasible to construct the proposed dry port. This location that is proposed is the old Durban Airport site. The site is located around 11km from the Port of Durban, and has a large amount of land available for construction. The site has connections to the DCT via road and rail. The road connection available is a dual carriageway highway. The rail that connects the two locations has a minimum of 3 tracks, and could provide a direct and efficient link the proposed dry port.

Figure 63 shows the first proposed site for the conceptual dry port, as well as the road and rail links to the site.

Figure 63 - Road and Rail Connections to Proposed Dry Port Site, Google Earth (2016)

Durban Dig-Out Port building lines

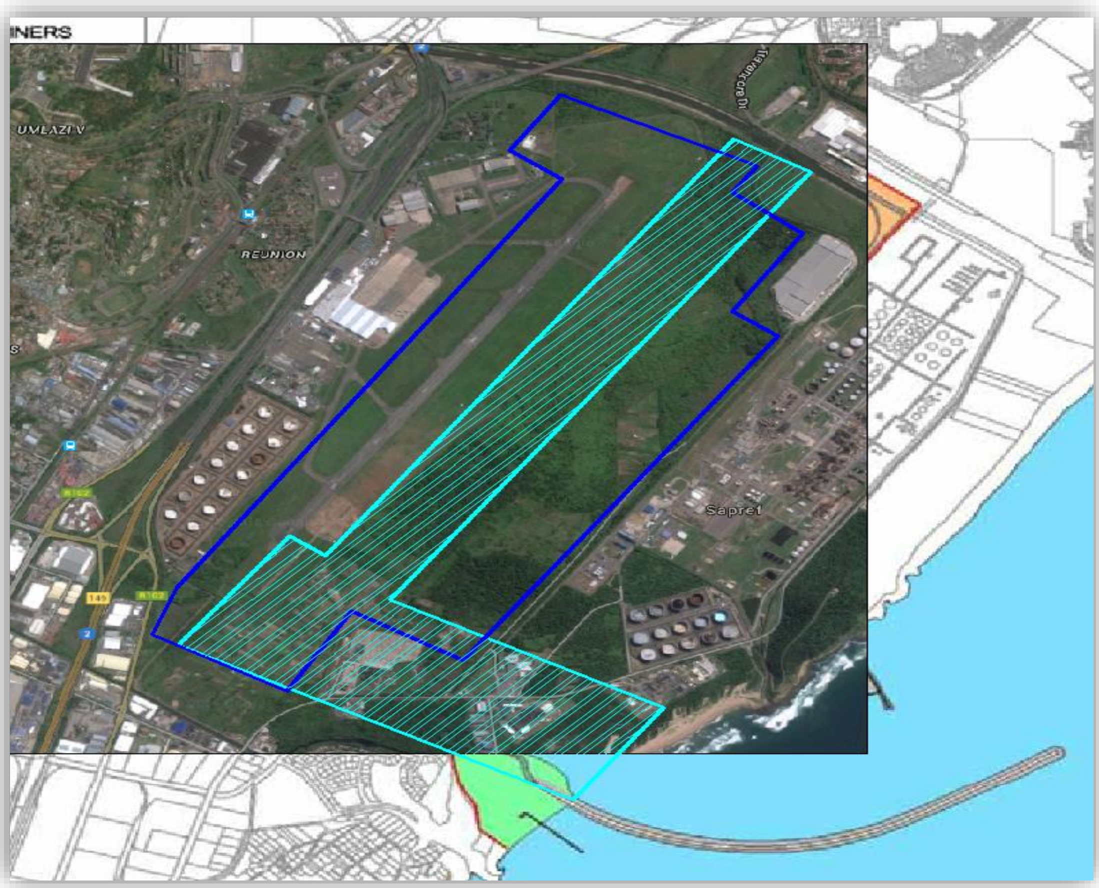
The Durban Dig-Out Port has been put on hold due to several reasons. There remains the possibility of approval to construct the port, thus, the dry port was designed in such a way that construction of the DDoP could still be accomplished in a cost-effective manner. The first step was to set out the building lines for the dry port.

Figure 64 - Proposed Durban Dig-out Port , MPoverello (2013)

Figure 64 shows an artist's impression of the DDoP, which is still being investigated as an alternative. Due to extent of the cost of excavation for such a port, the dry port was designed such that the main pavements and buildings befall outside of the main channel of the DDoP.

An aerial image of the proposed dry port was taken and superimposed with the plan of the dry port. This was done to achieve the lines for excavation, such that the construction of the DDoP could commence in the future without large financial implications.

Figure 65 represents the plan layout of the boundaries for the proposed dry port.



Building lines for dry port   Excavation lines for DDoP

Figure 65 - Proposed boundaries for new dry port

As indicated in Figure 65, the excavation lines will form part of the design, whereby no container stacking will take place in between those lines. By doing so the costs of construction of the DDoP are minimised, and the dry port can be upgraded to a dig out port.

D.2 Ground slots calculation

The calculation for the number of ground slots followed the same method stated by Bestenbreur (2015)- see Equation 4 The number of ground slots required is a function of the type of stacking strategy, dwell time and other factors.

The dwell time for the dry port was taken as 7 days, due to the reduction in dwell time for the maritime ports. The number of ground slots for two types of stacking systems: RTG and Straddle Carrier System were calculated, to determine the type of equipment to use for the dry port.

Table 41 shows the calculation for the total number of ground slots required for the dry port.

Table 41 - Calculation for required no. groundslots

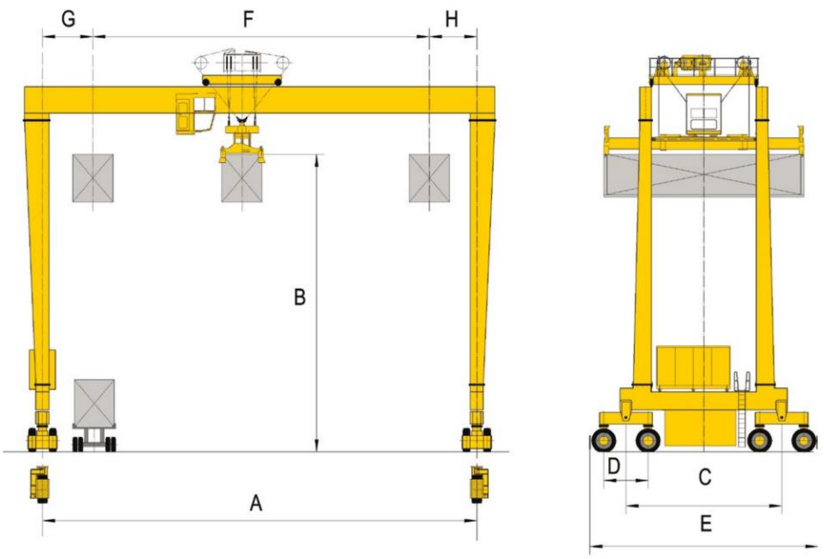
Characteristic	***Unit***	***Dry Port RTG "1over5"***	***Dry Port RTG "1over6"***	***Dry Port Straddle Carrier***
Transhipment	%	15	15	15
PF- Peak factor	-	1.1	1.1	1.1
TEU Factor	-	1.6	1.6	1.6
Dwell time	days	7	7	7
Max. effective stacking height	Containers	5	6	3
Average stacking height	Containers	3.5	3.75	2.5
n1 = Average stacking height/Max. Effective stacking height	-	0.7	0.62	0.83
n3 = Ground slots Utilized/Ground slots available	-	0.9	0.9	0.95
n2 = Peak average stacking height/average stacking height		1.0	1.0	1.0
Q(di) + Q(lo)	Cont. moves/year	4 375 000	4 375 000	4 375 000
Container Stacking Yard Capacity	TEU moves/year	7 000 000	7 000 000	7 000 000
Required number ground slots	-	**43 364**	**40 799**	**57 745**

Table 41 shows the calculation to determine the number of ground slots required in the dry port. The researcher performed the calculation for three different stacking systems. The Straddle Carrier system was not suitable for the dry port, due to the massive amount of ground slots. The next step was to calculate if the location for the proposed dry port could accommodate the amount of ground slots that were calculated above.

D.2.1 Stacking System

Section 2.6.2 analysed the advantages and disadvantages for the various container handling/stacking equipment. The RTG "1 over 5" system was chosen to handle the throughput for the dry port. This was chosen due to the low maintenance costs, and the larger storage capacity (has a larger TEU/ha than straddle carrier system). The RTG system runs in conjunction with a tractor/trailer system to transport containers to and from the container stacks.

Figure 66 shows the dimensions for a typical RTG "1 over 5" crane:



Where: A: 23.6m

B: 18.2m

C: 9.2m

D: 2.5m

E: 13.3m

F: 18.8m

G: 2.4m

H: 2.25m

Figure 66 - Typical RTG dimensions, Liebherr (2016)

Stacking Module

To determine if the dry port location can handle the desired throughput, a stacking module needs to be established. The stacking module ensures an efficient calculation of the number of ground slots required.

Figure 67 shows the stacking module that was chosen.

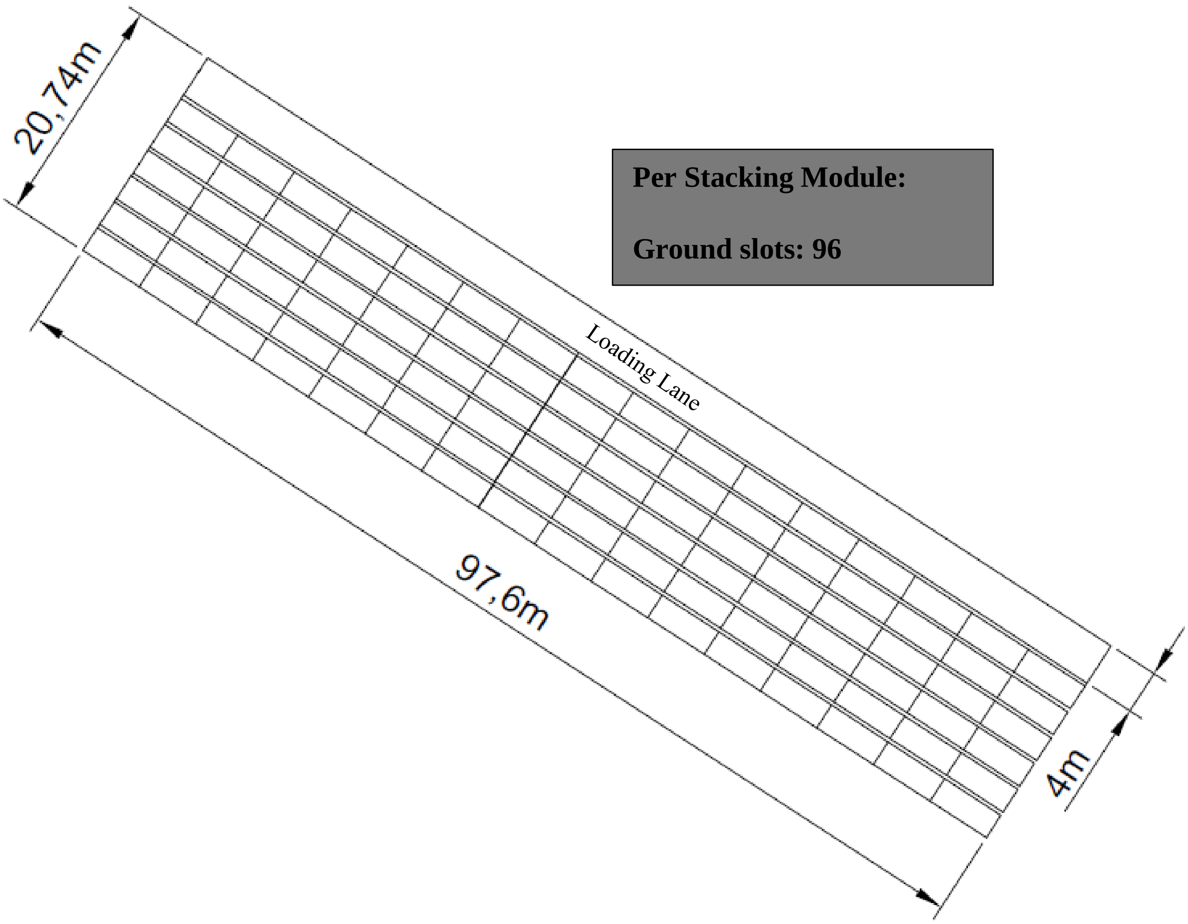


Figure 67 - Stacking Module for proposed dry port

Figure 67 shows that the above module yields **96 TEU ground slots**. To handle the proposed throughput, it was calculated that the dry port **requires 450 stacking modules**. Each module would be served **by one RTG crane**.

The spacing between the stacks was taken as 10m, every 4 stacks wide, and 20m between adjacent stacks – See Figure 68:

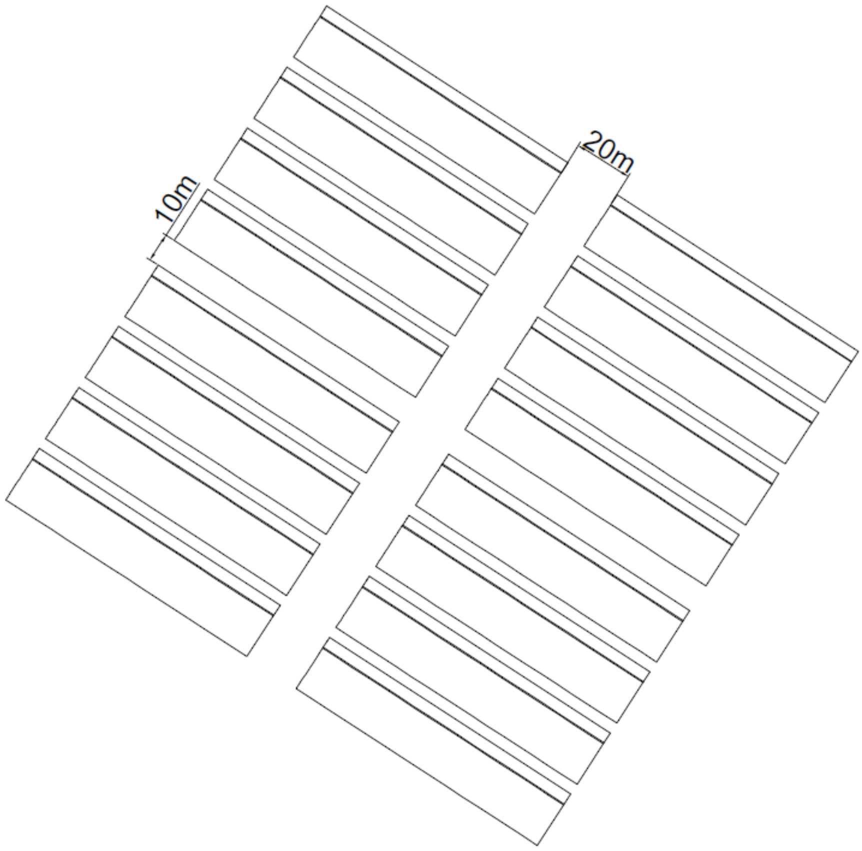


Figure 68 - Stacking layout

D.3 Dedicated Shuttle Train

It was found that a dedicated shuttle train service between the two ports would be the most efficient and cost effective. The purpose of this section is thus to calculate the number of trains and that would have to transport containers between the proposed dry port and the DCT. Due to the reduction of dwell time at the DCT, containers need to be transported as soon as possible to the dry port. The total number of TEUs/day to travel between the DCT and the dry port was calculated as follows:

$$Total\ throughput = 7\ 000\ 000 \frac{TEU\ moves}{year}$$

$$Total\ throughput = 4\ 375\ 000\ \frac{Cont\ moves}{year}$$

$$Total\ throughput\ to\ dry\ port = 4\ 375\ 000 \times (1 - Tr\ \%) = 4\ 375\ 000 * 0.85$$

$$= 3\ 718\ 750\ \frac{Cont\ moves}{year}$$

$$Total\ throughput\ per\ day = 3\ 718\ 750 \times \frac{PF}{365} = 3\ 718\ 750 * \frac{1.1}{365}$$

$$= 11\ 207\ \frac{Cont.}{day}\ (import\ and\ export)$$

$$Total\ throughput\ per\ day\ (TEU) = 11\ 207 * 1.6 = 17\ 931\frac{TEU}{day}\ (import\ and\ export)$$

The number of trains required is dependant on the number of containers being transported between the dry port and DCT. It was assumed that **the rail would handle 100%** of the containers between the two ports. The trains would have to be specially designed with repulsion units on both sides, so that it doesn't need to turn around between the two terminals.

The calculation for the number of trains was calculated as follows:

$$Train\ length = 750m = 48\ wagons = 96\frac{TEU}{train} = 60\ Cont/train$$

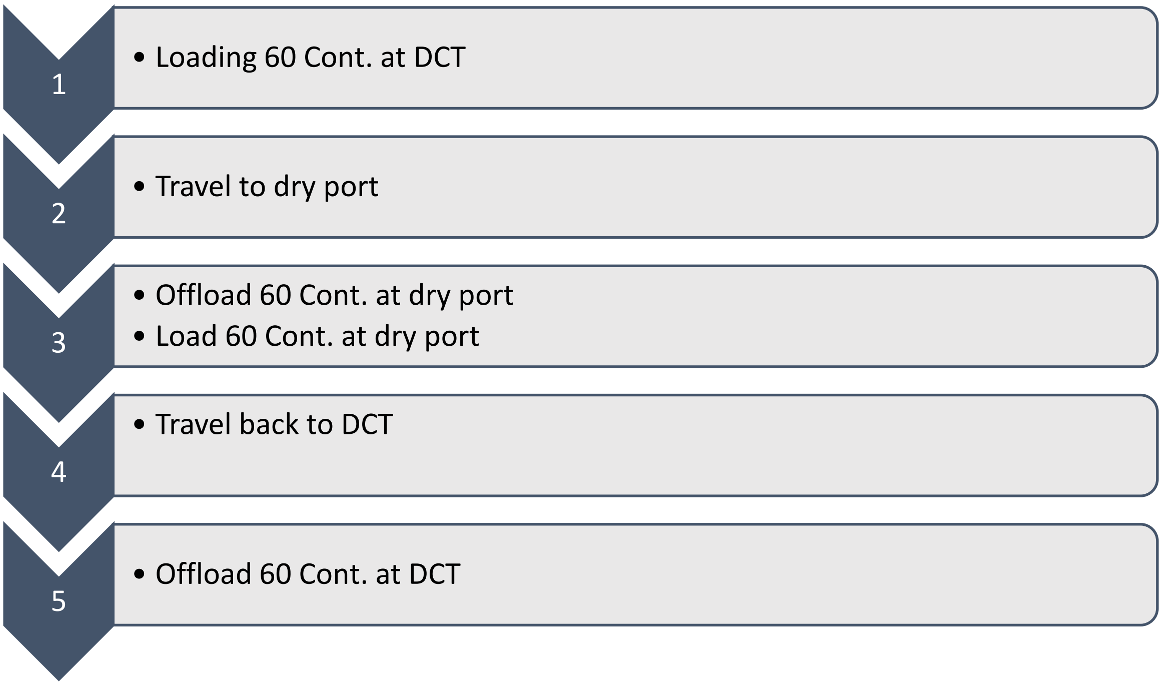
$$Total\ throughput\ via\ rail\ per\ day\ (Cont.) = 11\ 207\frac{Cont}{day}\ (import\ and\ export)$$

$$Thus:\quad 5603\ \frac{Cont.}{day} \Rightarrow To\ Dry\ Port = 93\ Train\ Loads\ per\ day\ (\frac{5603}{60})$$

$$Thus:\quad 5603\ \frac{Cont.}{day} \Rightarrow From\ Dry\ Port = 93\ Train\ Loads\ per\ day$$

The next step was to calculate the train turnaround time for the trains moving between the DCT and the proposed dry port.

Sequence Daily



Sequence per Train

This section shows the calculation for the train turnaround time, required to calculate the number of trains per day. The total train turnaround time is shown in Table 42.

Table 42 - Sequence to calculate train turnaround time

Description	***Time Required – Old Airport site***	***Comment***
Loading 60 Cont.	1 hr	3 RMG cranes at 20 Cont. moves/gch
Travel to dry port	45min	
Discharge/offload 60 Cont.	1 hr	3 RMG cranes at 20 Cont. moves/gch
Loading 60 Cont.	1 hr	As above
Travel back to DCT	45 min	
Discharge/offload 60 Cont.	1 hr	As above
Inefficiencies	2 hours	Shunting, time lost to delays
Total Train Turnaround Time	**7 hrs 30min**	**Take as 8 hours**

From the train turnaround time the following calculations were made:

Old Airport Site

$$No. of\ trips\ per \frac{train}{day} = \frac{24hrs}{8} = 3$$

$$No. of\ required\ trains = 93\ train\ loads\ \div 3 =\ 31\ trains, doing\ 3\ trips\ per\ day$$

$$Assume\ 4\ trains\ make\ use\ of\ 1\ track\ thus:$$

$$No. of\ tracks\ required \frac{31}{4} = 8,$$

$$Thus: \quad 8\ tracks\ are\ sufficient$$

From the calculation shown 8 tracks are necessary for the dry port shuttle train terminal. The current rail network that runs from the DCT past the location of the dry port contains 4 tracks. The infrastructure would have to be upgraded to handle the container traffic, generated by the dedicated shuttle train service.

D.4 Truck Loading Bay Terminal

The calculation for the number of truck loading bays was done per the formula stated below (researcher formula). It was assumed that the truck terminal would handle **40% of the total throughput.** The max number of trucks per day was calculated by assuming a turnaround time of 15 min, thus the number of trucks per day = 24/(15/60). The formula that was used to calculate the number of loading bays was as follows:

$$No. of\ truck\ loading\ bays$$
$$= \frac{(Max\ No. containers\ per\ year\ through\ terminal) * (1 - Tr\%) * PF * 0.4}{(No. trucks\ per\ day\ ) * (No. containers\ per\ truck) * \left(Working \frac{days}{year}\right) * Operational\ factor}$$

$$= \frac{\left(\frac{7000000}{1.6}\right) * (1 - 0.15) * 1.1}{(24/0.25) * (1) * (365) * 0.8} = 58$$

The number of required **loading bays was taken as 60**, as a conservative approach. It was decided that the truck terminal be operated by straddle carriers, which would only serve the truck terminal. The tractor/trailer system would bring containers from the stacks and be lifted directly in the buffer zone and loaded onto the dedicated truck.

D.5 Rail Terminal

It was calculated that the shuttle train service requires 6 tracks for loading/off loading. Due to the dedicated shuttle train service that was proposed to operate between the DCT and the dry port, it was decided to design **two rail terminals**. One terminal would serve the shuttle trains, and the other would serve all containers that arrive/depart the dry port for a destination besides the DCT. This was considered necessary to alleviate congestion problems in the dry port.

The number of tracks required to for the hinterland terminal was calculated as follows:

$$Total\ throughput = 4\ 375\ 000\ \frac{Cont\ moves}{year}$$

$$Total\ throughput\ to\ dry\ port = 3\ 750\ 000 \times (1 - Tr\ \%) = 3\ 750000 * 0.85$$

$$= 3\ 718\ 750\ \frac{Cont\ moves}{year}$$

$$Total\ throughput\ through\ hinterland\ terminal\ per\ day\ (60\%\ modal\ split)$$

$$= \frac{3\ 718\ 750 * 0.6 * 1.1}{365}\ \left(\frac{Cont.}{day}\right)$$

$$= 6724\ Cont./day$$

$$Train\ length = 750m = 48\ wagons = 96\frac{TEU}{train} = 60\ Cont/train$$

$$Total\ throughput\ via\ rail\ per\ day\ (Cont.) = 6724\ (import\ and\ export)$$

$$Thus: \quad 3362\ \frac{Cont.}{day} \Rightarrow To\ Hinterland = 56\ Train\ Loads\ per\ day\ (\frac{3362}{60})$$

$$Thus: \quad 3362\ \frac{Cont.}{day} \Rightarrow From\ Hinterland = 56\ Train\ Loads\ per\ day$$

$$Max\ No.of\ trains\ per\frac{track}{day} = \frac{24hrs}{3} = 8$$

$$No.of\ required\ trains = 56\ trains\ doing\ 1\ trip\ per\ day\ (assumed\ due\ to\ long\ distances)$$

$$Assume\ 8\ trains\ make\ use\ of\ 1\ track\ thus:$$

$$No.of\ tracks\ required\ 56/8 = 7\ tracks\ are\ sufficient$$

From the above calculations, it was found that the hinterland rail terminal would require 7 tracks to handle the daily container throughput to the hinterland market. The shuttle train terminal would have to be served by 8 tracks. The train lengths were taken as 750m for both terminals.

D.6 Layout of dry port

The design of the dry port was performed on AutoCad and the final overall layout can be seen in Figure 69:

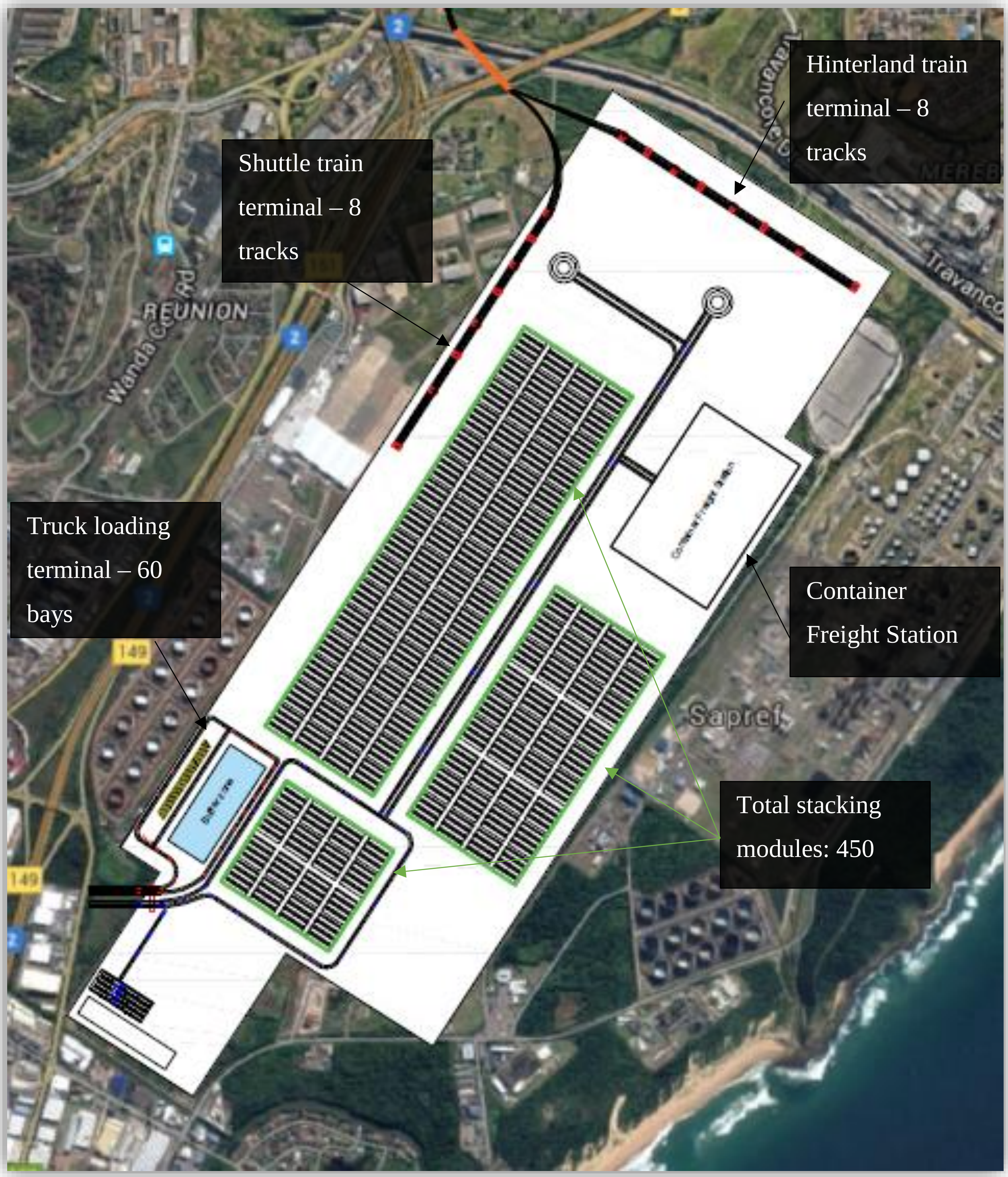


Figure 69 - Layout of dry port at old Durban Airport site